Univ. of
Toronto
Library

Digitized by the Internet Archive
in 2010 with funding from
University of Toronto

http://www.archive.org/details/specialreportser16medi

NATIONAL HEALTH INSURANCE.

MEDICAL RESEARCH COMMITTEE.

A Report on the Causes of Wastage of Labour in Munitions Factories employing Women.

UNIVERSITY OF TORONTO
AUG 6 1919
LIBRARY

LONDON:
PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE.

To be purchased through any Bookseller or directly from
H.M. STATIONERY OFFICE at the following addresses:
IMPERIAL HOUSE, KINGSWAY, LONDON, W.C. 2, and 28, ABINGDON STREET, LONDON, S.W. 1;
37, PETER STREET, MANCHESTER; 1, ST. ANDREW'S CRESCENT, CARDIFF;
23, FORTH STREET, EDINBURGH;
or from E. PONSONBY, LTD., 116, GRAFTON STREET, DUBLIN.

1918.

Price 1s. 6d. *net.*

NATIONAL HEALTH INSURANCE.

MEDICAL RESEARCH COMMITTEE.

The following publications relating to the work of the Medical Research Committee can be purchased through any bookseller, or directly from H.M. Stationery Office, at the following addresses: Imperial House, Kingsway, London, W.C. 2, and 28, Abingdon Street, London, S.W. 1; 37, Peter Street, Manchester; 1, St. Andrew's Crescent, Cardiff; 23, Forth Street, Edinburgh; or from E. Ponsonby, Ltd., 116, Grafton Street, Dublin.

First Annual Report of the Medical Research Committee, 1914–1915. [Cd. 8101.] Price 3*d.*, post free 4*d.*

Second Annual Report of the Medical Research Committee, 1915–1916. [Cd. 8399.] Price 3½*d.*, post free 5*d.*

Third Annual Report of the Medical Research Committee. [Cd. 8825.] Price 6*d.*, post free 7*d.*

Special Report Series.

No. 1. First Report of the Special Investigation Committee upon the Incidence of Phthisis in relation to Occupations.—The Boot and Shoe Trade. Price 3*d.*, post free 4*d.*

No. 2. Report of the Special Advisory Committee upon Bacteriological Studies of Cerebro-spinal Fever during the Epidemic of 1915. Price 6*d.*, post free 7*d.*

No. 3. Bacteriological Studies in the Pathology and Preventive Control of Cerebro-Spinal Fever among the Forces during 1915 and 1916. Price 1*s.* 6*d.*, post free 1*s.* 8*d.*

No. 4. Reports upon Investigations in the United Kingdom of Dysentery cases received from the Eastern Mediterranean.

I. Amœbic Dysentery and the Protozoological Investigation of Cases and Carriers. Price 1*s.*, post free 1*s.* 2*d.*

No. 5. II. Report upon 878 Cases of Bacillary Enteritis. Price 1*s.* 6*d.*, post free 1*s.* 8*d.*

No. 6. III. Report upon Recovered Cases of Intestinal Disease in the Royal Naval Hospital, Haslar, 1915–16.

IV. Report upon combined Clinical and Bacteriological Studies of Dysentery Cases from the Mediterranean. Price 1*s.* 6*d.*, post free 1*s.* 8*d.*

No. 7. V. Report upon 2,360 Enteritis "Convalescents" received at Liverpool from various Expeditionary Forces. Price 2*s.*, post free 2*s.* 2*d.*

No. 8. Report upon Soldiers returned as Cases of "Disordered Action of the Heart" (D.A.H.), or "Valvular Disease of the Heart" (V.D.H.). Price 1*s.*, post free 1*s.* 2*d.*

No. 9. A Report upon the use of Atropine as a Diagnostic Agent in Typhoid Infections. Price 1*s.*, post free 1*s.* 2*d.*

No. 10. The Mortalities of Birth, Infancy, and Childhood. Price 1*s.* 6*d.*, post free 1*s.* 8*d.*

No. 11. The Causation and Prevention of Tri-nitro-toluene (T.N.T.) Poisoning. Price 1*s.*, post free 1*s.* 2*d.*

No. 12. The Classification and Study of the Anærobic Bacteria of War Wounds. Price 2*s.*, post free 2*s.* 2*d.*

No. 13. An Enquiry into the Composition of Dietaries, with Special Reference to the Dietaries of Munition Workers. Price 3*d.*, post free 4*d.*

No. 14. Reports of the Special Committee upon the Standardization of Pathological Methods.

No. I. The Wassermann Test. Price 3*d.*, post free 4*d.*

No. 15. A Study of 1,300 Convalescent Cases of Dysentery from Home Hospitals; with special reference to the Incidence and Treatment of Amœbic Dysentery Carriers. Price , post free .

No. 16. A Report on the Causes of Wastage of Labour in Munitions Factories Employing Women. Price 1*s.* 6*d.*, post free 1*s.* 8*d.*

The following is published under the direction of the Medical Research Committee by Messrs. Longmans, Green & Co., 39, Paternoster Row, London, E.C. 4.

Milk and its Hygienic Relations, by Janet E. Lane-Claypon, M.D., D.Sc. (Lond.). Price 7*s.* 6*d.* net.

NATIONAL HEALTH INSURANCE.

MEDICAL RESEARCH COMMITTEE.

A Report on the Causes of Wastage of Labour in Munitions Factories employing Women.

154389
17/2/20.

(*Approved for publication by the Medical Research Committee, 7th December, 1917.*)

Medical Research Committee.

(National Health Insurance.)

The Hon. WALDORF ASTOR, M.P. (*Chairman*).

The Right Hon. CHRISTOPHER ADDISON, M.D., M.P.

The VISCOUNT GOSCHEN, C.B.E. (*Treasurer*).

C. J. BOND, C.M.G., F.R.C.S. (Hon. Colonel).

A. K. CHALMERS, M.D., D.P.H. (Lieut.-Colonel R.A.M.C. (T.)).

Professor WILLIAM BULLOCH, M.D., F.R.S.

Professor F. G. HOPKINS, D.Sc., F.R.S.

Colonel SIR WILLIAM LEISHMAN, C.B., F.R.S.

Professor G. R. MURRAY, M.D., F.R.C.P. (Major R.A.M.C. (T.)).

SIR WALTER M. FLETCHER, K.B.E., M.D., F.R.S. (*Secretary*).

15, BUCKINGHAM STREET,
STRAND, W.C. 2.

R
111
M457
no. 16-24
cop. 2

(B2367) Wt. 6417—953. 1000. 5/18. Sir J. C. & S. **Gp. 32.**

INTRODUCTION.

To the enquiry of which the results are given in the present Report the Medical Research Committee offered assistance as part of their co-operation in the investigations of various kinds conducted on behalf of the Health of Munition Workers' Committee. The employment of women upon an immense scale in munition factories and workshops seemed to provide a unique opportunity for determining the results, so to speak, of a gigantic experiment, in which women were exposed by the national necessities to an unfamiliar stress of factory life. The simultaneous and systematic organisation of this female labour in many parts of the country at once, under central control by the Ministry of Munitions, allowed statistical data to be secured without an undue expenditure of clerical labour and in numbers sufficient to give the results real significance.

The proper mobilisation of women for national tasks, like that of men, is fundamentally a medical problem, and the measure of the success achieved in it, expressed in terms of the rate of disappearance of recruits unsuitably enlisted, seemed likely to yield information of a new and valuable kind. But the results have shown that the rates of loss by the falling out of women from the employed ranks at given tasks were too high to be accounted for in terms of physical unfitness alone. As Captain Greenwood points out in his report, it must be taken as being definitely established that the "existing rates of loss in manufactories are unnecessarily high, and that so long as they continue the effective mobilisation of labour for national service has not even been approximately realised. When expressed in terms of the whole munition making female population, the avoidable losses must amount to many thousands." Avoidable loss means here in the main a loss not due to physical incapacity or ill-health. The causes at work in producing it must receive their explanation elsewhere, and must indeed remain unexplained until they can be expressed by further analysis in terms of social and economic factors through the organised studies of welfare workers and the systematic "following up" of absentees. This side of the problem, however, lies outside the sphere of medical research.

Nevertheless, some broad results of medical interest emerge clearly from Captain Greenwood's work. The collected facts show that the general strain of factory life in itself is not borne worse by elder than by younger women, but that when the general wear and tear of factory conditions is combined with physical labour of more than a light or medium degree, women over 23 years of age cannot as a whole stand the strain so well as their juniors. We are speaking here only of women engaged during physical maturity, and not in the decline of life, and yet the difference between the junior and senior members of this young adult class is well marked. As Captain Greenwood

concludes, "it is distinct enough to make an attempt at systematic recruiting of the older women for the physically lighter labour and of the younger women for the more strenuous tasks worthy of practical attention." There seems little doubt that the explanation is to be found, as he suggests, in the fact that the senior women will in larger proportion be married and have young children than their juniors, and will obviously be less likely to have the same reserves of strength and energy for the double demand made upon them at home and in the factory.

The thoroughness with which Captain Greenwood has availed himself of the exceptional opportunities offered to him for this enquiry has appeared to the Committee to justify, even at the present time, the full presentation of his numerical data. These may long serve as a standard for reference when subsequent work of a similar kind is undertaken in the future.

CONTENTS.

	PAGE.
I.—Introduction	5
II.—Previous Investigations	7
III.—Statistical Methods Used	8
IV.—Preliminary Examination of Data	10
V.—Detailed Examination of a London Factory with Full Records	11
(*a*) Nature of Records	11
(*b*) Classification by Causes of Leaving	12
(*c*) Discussion of Findings	13
(*d*) Losses through Ill Health	15
(*e*) Comparison of Peace Time and War Time Results	15
(*f*) Comparison of Age Groups	16
(*g*) Comparison by Occupations	16
(*h*) Summary	16
VI.—Study of a Country Factory	17
VII.—Study of a Midland Factory	20
VIII.—Study of Factories on Heavy Work	22
IX.—General Comparison of Light and Heavy Factories	24
(*a*) Introductory	24
(*b*) Sources of Error	24
(*c*) Influence of Age	25
(*d*) Influence of Type of Work	26
(*e*) Discussion of Losses through Ill Health	27
(*f*) Local Variations	27
(*g*) Hours of Labour and Wastage	28
(*h*) Relation of Wastage to Previous Occupation ...	28
X.—General Conclusions	28
Appendix I.—Tabular Matter	30
Appendix II.—Note on Errors of Sampling	73

A REPORT ON THE CAUSES OF WASTAGE OF LABOUR IN MUNITIONS FACTORIES EMPLOYING WOMEN.

Made to the Health of Munition Workers' Committee
Ministry of Munitions of War)

MAJOR GREENWOOD

(WELFARE AND HEALTH SECTION MINISTRY OF MUNITIONS,

Statistician to the Lister Institute of Preventive Medicine;
Reader in Medical Statistics in the University of London;
Captain 1st London Sanitary Company R.A.M.C. (T.)

I.—INTRODUCTION.

The Health of Munition Workers' Committee have discussed various problems which offer themselves for solution when the object proposed is the greatest possible output of munitions purchased at the least possible cost of money, health and time. They have shown that certain hygienic standards ought to be established for the material conditions of the factories, that the hours of labour ought not to exceed a maximum which is different in different classes of work, that the exact organisation of day and night work is of moment and the system, as distinct from the amount, of wages remuneration by no means a matter of indifference. It has also been made probable that waste of time may be diminished by a heedful organisation of working periods. On the basis of these results various improvements have been suggested, some of which have now been carried into effect.

One very important matter has not, however, been discussed, viz., the regularity with which employees in munition factories continue to perform their tasks. Although it is true that a majority of the operations carried out in munitions factories do not require a high degree of manipulative dexterity, hardly any are such that practice does not lead to increased precision of work and therefore rapidity of output. Thus in the manufacture of cartridge cases, perhaps the simplest type of operations, all the Committee's investigators agree that an employee cannot attain her maximum degree of efficiency until she has been engaged some weeks on her task.

It follows, therefore, that a factory the operatives of which are constantly leaving and being replaced by new workers cannot attain the same level of output as one in which the working population is stationary, and it becomes of importance to obtain exact information as to the extent to which munition workers do move from their employment. In addition to the investigations of the Community that I should collect and submit to them data for a consideration of the problem, a preliminary report was published in May, 1917. Since that time my transfer to the headquarters of the Welfare and Health Section has enabled me to amass further material, and the report is less incomplete than would otherwise have been the case.

Discontinuity and intermittency of employment are a familiar topic to economists, the able study contained in the report of the Minority of the Royal Commission on the Poor Laws being well known. Some of the large factors influencing the variations of employment in peace time industries are, however, inapplicable to munition work in war time, and *pro tanto* the problem is simplified. We have not, for instance, to consider changes of demand: the demand for munitions is constant and practically infinite: neither have we to allow for the desire or alleged desire of certain employers to maintain a reserve or "stagnant pool" of intermittently employed hands. But there are other complications which if not peculiar to are at least intensified by war conditions. One of these applies directly to men and indirectly to women, viz., the increasing demand of the military authorities for recruits. This must tend to shorten the average expectation of industrial life among the men directly and among the women indirectly, since an increasing fraction of the latter will be drawn upon to fulfil necessary services outside the walls of munition factories when the men in question but not their normal occupations are removed.

The second complication more immediately concerns the women. In the flush of patriotic enthusiasm many women and doubtless not a few men, crowded into occupations of national importance, anxious to do their "bit." Some of these were unaccustomed to long hours of monotonous labour. They had not learned or perhaps had forgotten the bitter lesson of experience viz., that enthusiasm is no substitute for dogged endurance. Instead of attributing their discomforts to the true cause, they blamed their health or the hygienic surroundings of the factory, and occasionally concluded that some other form of national work would be more congenial and better suited to their abilities. This motive of change which in normal times is held in check by the fear that when a post is lost no other may be found has free play in the case of persons not forced to earn their bread and even operates upon accentuated wage earners when the demand for most sorts of labour is much greater than the supply.

II. Previous Investigations.

It is *a priori* impossible to say whether the conditions special to peace time work and absent from war work effectively balance those special to war work and not normally in action, but it seems desirable at the outset to ascertain how labour does fluctuate in any peace time industry, the conditions of which are tolerably stable. The most recent contribution to this subject comes from America, and is contained in a report of an investigation by Mr. Joseph H. Willits, carried out in Philadelphia and published under the title "Steadying Employment" in the Annals of the American Academy of Political and Social Science for May, 1916.

Many of the facts recorded in this interesting document are not relevant to the Committee's task, but the following are noteworthy. A particular shop in a carpet mill was intensively studied, it was chosen because the kind of work done to some extent avoided the variability of seasonal trades, fashion being a relatively unimportant element and slack seasons being utilised to manufacture for stock. The dates of engagement and discharge of the employees were tabulated for the period 1907–15, and the following results emerged:—Of males, employees hired between 1907–15 4 per cent. remained in employment over 5 years, 3 per cent. 4–5 years, 4 per cent. 3–4 years, 5 per cent. 2–3 years, 9 per cent. 1–2 years, and 75 per cent. less than one year. Forty-eight per cent. of the men and 37 per cent. of the women remained in the service of the firm less than ten weeks.

A wider but less detailed study made by Mr. Alexander of the General Electric Company, of a large number of factories of all sizes in the United States and Europe showed that on January 1st, 1912, 38,668 persons were employed in the factories studied, and on December 31st, 46,796, or an increase of 8,128. But the records also showed that in the interim 44,365 persons had been engaged, so that 36,237 had dropped out of employment during the year, or about 5½ times as many people had to be engaged as constituted the increase of forces at the end of the period.

These figures, as published, are not amenable to the analysis to which I have subjected certain munitions factory data to be discussed later on in this report, but it will be of interest to contrast them with some material which is also not suitable for detailed study.

I obtained from a large munitions factory the following figures:—

In effect, the number of women employed at the end of June, 1916, was 4,571, and at the end of October 6,237, an increase of

1,666. During this period 2,791 were engaged and 1,125 left. The number of engagements being 167·5 per cent. of the net increase in four months. Here also we see suggested a very large amount of discontinuity, and it is to be remarked that while in these months, together with the previous month (June) the firm lost 1,516 female employees, in only 663 cases—or 43·7 per cent.—was the cause of leaving known to the firm, the balance of 56·3 per cent. having simply vanished. These statistics are quite inadequate to permit us to unravel the causes of changing employment, but they illustrate its importance and show that the problem merits further investigation.

III.—Statistical Methods Used.

Before detailing such investigations, it will be appropriate to describe the methods of analysis which seem suitable to the case.

The form in which we desire to express our statistics is analogous to that of an ordinary life table. We wish to know how many out of some basis number, say 1,000, starting to work will still be employed at the end of one month, two months, three months, &c. Mr. Willits has expressed his results in this form, but it is not clear from the summarised statement how the rates were computed and whether "exposed to risk" totals were formed and rates of loss ascertained, or how the entrants still at work were treated; in a word, whether the summary relates exclusively to completed industrial lives. Assuming that we should proceed by the life table method, there are two distinct possibilities. The first involves the preparation of a separate card or slip for each entrant during the period of exposure studied.

Suppose for instance that we are investigating all the employees at a certain factory who entered between 1st June and 31st December, 1915, and had left by, *or were still at work on*, 1st January, 1916. We shall (supposing for the sake of illustration that we do not use a finer unit of time than one month) prepare a series of cards upon each of which is entered the number of months each employee had remained in service, neglecting odd weeks, in the case of those who had left, or the nearest number, reckoning a duration of less than two weeks as zero, a duration of two weeks to one month as one month, &c., in the case of those still employed. From these cards we can build up the population exposed to risk of leaving for each month of service. Thus, the population exposed to the risk of leaving in the first month of employment will consist of:—

(1) All those still at work after a month's service.
(2) All those who had left after having served at least a month.
(3) All those who left in the first month.

So that the rate of loss in the first month will be (3) divided by (1) plus (2) plus (3). Similarly for the next month we obtain the exposed to risk by subtracting the number leaving in the first month and the number still at work, but only having been at work for a single month (and therefore not exposed to the risk of leaving in the second month).

This is a method often used in assurance offices for preparing the crude or unadjusted rates of mortality among their policy holders, and the assumptions and approximations involved will be found discussed in works on actuarial technique.*

The second, sometimes called the census method, is less accurate, but requires also less minuteness of treatment. Suppose we wish to study the industrial life table, as we may call it, for the period of 1916, which we will suppose divided into thirteen lunar months of four weeks. Suppose that we know the number of entries and the number of losses during each month of 1915 and 1916. Suppose, further, that the losses of each month are classified into those who had been employed not more than one month, those that had been employed from one to two months, from two to three months, &c.

Then, on the assumption of losses and gains being uniformly distributed throughout the month to which each figure relates, it is easy to determine the rate of loss for each period of employment as experienced during 1916. The numbers leaving with less than one month's service during each month of 1916, divided by the sum of the entrants in each month, except the last of 1916, with the addition of half the entrants in the last month of 1915 and half the entrants of the last month of 1916 will give the rate of loss for the first month of service. The "exposures" in the second month of service will be the sum of half the entrants in the last month but one of 1915, all the entrants from the last month of 1915 to the last month but two of 1916 and half the entrants in the last month but one. From these are to be subtracted the losses in the first month of service from the last month of 1915 to the last month but one of 1916 (inclusive). The losses in the second month of service during 1916 divided by this sum will give the rate of loss in the second month of service; this method can be carried back to the eleventh month of service if data for two years are available, and is practically the ordinary process used in preparing the data for a general life table, in the case of the early years of life, except that we have omitted the adjustment of the exposed to risk by comparison with the census population, that is the actual mean numbers of employees at work during the year 1916, and the subsequent graduation of the rates.

* A very clear non-technical account is contained in Elderton and Pitford's "Construction of Mortality and Sickness Tables" (Black) 1914. More complete information can be found in Blaschke's "Vorlesungen über Mathematische Statistik" (Teubner) 1906.

IV.—Preliminary Examination of Data

One or other of these methods has been used in reducing the munition data. The first set of data obtained was not complete enough to allow either of these processes to be employed in its entirety, and a portion of the particulars set out in Tables 2–4 They come from the cordite department of a large munitions factory

Taking Table 4 first for the full year from August 28th, 1915 to August 28th, 1916 we find that an increase of 624 has been the result of 1031 new engagements among men while 914 accessions have been obtained by 1527 new entrants among women, percentages of 165 and 167 respectively which compare favourably with the almost identical ratio of 167 per cent in the case of the munition firm data quoted above, and relating to a period of only five months and also favourably with the pearl-time ratio given in the American report

The second method of reduction outlined in the previous description cannot, however, be satisfactorily applied to these data. Not only is the period for which losses are classified by length of service restricted to seven months but in addition the total losses for these months do not agree with the detailed losses set out in Tables 2 and 3. In the case of the women, as the total losses of Table 4 for the seven months are greater (476 against 416) than the losses classified by length of service the presumable explanation is that some girls left without particulars of their length of service being recorded. But in the case of the men the totals from the detailed table is larger than that of the summarising table, so that some confusion with employees in another department of the works must have occurred. Lastly the time intervals are unequal, being calendar months, or in the case of the first period, five weeks.

For these reasons it is futile to prepare averages purporting to bear comparison with exact rates of losses computed by any actuarial method. As a matter of curiosity however a calculation was made on the assumption that the intervals of time were really equal and that the rates of loss for different periods of service shown for the seven available months still applied to earlier experience. With these assumptions, it appeared that the rates of loss were approximately as shown in Table 5 from which we deduce that among the girls some 36 per cent of entrants will have left by the end of the seventh month from entry, and a rather smaller percentage of the men. Thus, although comparing favourably with the Carpet Mill returns obtained by Mr Willits, shows a considerable absolute loss but the basis of computation is so conjectural that it would be quite improper to attach more than the slightest degree of importance to the figures until controlled by more precise data.

V.—Detailed Examination of a London Factory, with Complete Records

(A) *Nature of Records*

The next set of data merits closer attention and is worthy of completer analysis. It is discussed in full detail, both to illustrate the method and because its extent and accuracy are greater than attained by any other set studied.

The data were collected in a munitions factory of high standing, the investigators being afforded every facility in consulting and tabulating the very full records kept.

The factory is at present organised in two main departments, one producing cases and bullets (the other carrying out cartridge and grenade filling operations. The distinction is not absolute, but it is roughly true to say that the former does not handle explosives while the latter does. hereafter the two are denoted by L.1 and L.2 respectively. The firm has for some years previously maintained a card index system, and the name, age, previous occupation, character, and reason for leaving has been recorded in nearly every case since 1910. Particulars of entry are indeed available back to 1907, but it does not appear that details as to discharge were universally recorded prior to 1911. This investigation is therefore confined to the period from January 1st, 1911, to December 1st, 1916. The whole of the cards were copied each upon a separate slip (I have to thank Mr. S. H. Burchell for undertaking this tedious work), and the duration of employment of each girl computed in the way described above.

The computed durations are not strictly accurate as the differences of length of the calendar months have been ignored; the practical error so introduced is quite unimportant in the present connection.

The data were classified into two main groups:—(1) covers the entrants from 1st January, 1911, to 4th August, 1914, and the rates of loss are deduced from the numbers leaving within the same period out of the entrants. (2) deals with entrants from 4th August, 1914, to 1st December, 1916, the rates of loss similarly depending on the experience of that period. An analysis was also made of the rates of loss since the war among employees who having been engaged before the war, but since 1st December, 1911, were still at work for varying periods after the 4th August, 1914. The numbers in this category were, however, quite inadequate to provide useful tabulations (451 girls and women), and are not here discussed. In each of the two main groups four sub groups were formed consisting respectively of girls and women aged 13-17 inclusive, 18-22, 23-27 and 28 or over at the time of engagement. The actual number of separate engagements

dealt with was 8,818.* This is larger, of course, than the number of separate girls as there were numerous re-engagements. Evidently, however, for our purposes, the re-engagements should be the fundamental data. These different groups were then analysed by months from 0 to 24 (*i.e.*, those leaving after twenty-four months were counted as "existing at the close of the period"), it having been found on preliminary trial that the data were insufficient to provide rates for later months; indeed, as it is, the rates for months beyond the sixth or seventh are evidently subject to large errors of sampling, and have little value.

(B) Classification by Causes of Leaving.

The causes of leaving were classified into three categories:—

(1) Those who left on account of ill health.

(2) Those who left for some sufficient reason other than that of health.

(3) Those who left for no reason or for an insufficient one.

The meaning and limitations of the classification which has been used in all subsequent analyses must be fully grasped. (1) needs little comment save to remark that the diagnosis of ill health has not necessarily been made by a medical man, but in an unascertainable proportion of cases merely the girl's statement, and that girls who left after an accident are included. Under (2) were comprised (*a*) girls who left to be married; (*b*) girls who were moving from the district; (*c*) girls required at home on account of illness there, or in the case of married women to keep house; (*d*) girls who found the wages earned insufficient; (*e*) girls discharged by the firm not for misconduct, but because they were unsuitable or because work was slack; (*f*) girls considered by the factory surgeon to be physically unfit, although not complaining of illness. Under (3) were grouped (*a*) girls who left without giving any reason at all; (*b*) girls discharged for misconduct; (*c*) girls leaving for other employment without assigned reason; girls wanting a change, or "dissatisfied" or

* Sixty-five male slips were omitted into occupational groups than were used in the tables at issue. Nearly all these are accounted for by the number of girls left at work who had been engaged less than two weeks prior to the conclusion of the period of observation. As a rule of the observations in the group were 13–17 in the first setting it not explicable in this way, and is due either to a mistake in counting or setting. It having been found that no sensible difference would be made in the rates by the discrepancy, the tabulation was not re-checked. In addition to the slips used for tabulation thirty-one other entries were found which did not record all the particulars. No use could be made of these. The register also contained the names of 865 girls and women engaged before 1st January, 1911, who were still at work or had been discharged between 1911–17. For the reasons stated in the text these data were not available for the investigation.

stating the work to be "unsuitable." It may be mentioned that a large majority of (3) consisted of the girls giving no reason at all, whom we may colloquially term the vanishing girls.

(c) *Discussion of Findings.*

Tables 6–21 were prepared in the manner above described, and Table 22 gives the distribution of the peace time and war time entrants by occupations prior to entry. In these, and subsequent tables, the first column gives the month of service, *e.g.*, the figure one means the *second* month of service, while the second column records the number which was exposed to risk of leaving in that month.

A feature common to all the tables is the heavy rate of loss in the first two or three months' service. It is to be especially remarked that the rate of loss in the first month is a minimum figure. In addition to the girls registered in the firm's card index, 1,420 girls are known to have worked in the factory between 1910 and 1917 for periods varying from a few minutes to a few days. These cases are really industrial still-births never deemed to have a separate industrial existence, or, to vary the metaphor, they may be regarded as visitors, not residents. Clearly, their inclusion would suffice to double the rate of loss in the first month. Since the criterion adopted by different firms as to what girls shall be registered as definitely engaged may vary, rates of loss during the first month can only be compared when due allowance has been made for any such difference of system. Rates of loss in the second and subsequent months are not in general subject to this criticism.* A second characteristic is the large proportion of losses for which no satisfactory reason can be assigned. Taking the general table (7) as an illustration, it appears that of 1,000 girls entering the factory 132 will not outstay the second month. Even had there been *no* loss from sickness or from other reasonable cause the 1,000 would still have been reduced by 10 per cent. for no sufficient reason. (*See also* Table 23.) As this is a minimum figure (still births excluded), and is the experience of a firm of high standing thoroughly familiar with the industry which they have not entered upon for the first time since the war, it is evident that the absolute losses of hands occurring in munition factories are serious. Workers leaving with less than two months' service can, on the average, have made but very small contributions to the output of munitions. While, on the debit side of the account we must enter the trouble to which they have put the officials of labour bureaux and the administrative staff of the factory as well as, in some cases, the demands made upon the transport facilities of the country. In the light

* It is, however, important to remember that in some factories girls are not struck off the books as having definitely left until after the expiration of several weeks. This will sometimes explain a sudden rise in the rate of loss during the second or third service months.

of our new tables we may fitly return to the case of Table 1 and estimate whether the factory showing those results was losing hands at a greater rate than the one here specially considered. First as to the numbers of those said to have started in each month who could still be present at the end of October. Using the appropriate rates from Table 7, we calculate that of the 3,413 entrants into Shop 32 would have been lost by the end of October. We have no information as to the distribution by length of service of the 4,340 already at work on June 1st, but assuming 14 per cent. to have been in their first month, 16 per cent. in their second month, 18 per cent. in their third, 20 per cent. in their fourth, and the remainder in the fifth month of service, we should expect 859 to be lost on the total losses to have been 1,201. Actually they were 20 per cent. more than this. Until, however, we know to the difference made by the system of registration we cannot be certain that this is really a worse result than would have been found in the other factory.

Turning to the data of Tables 2-5. The proper comparison is with Table 8, as the factory providing Tables 2-5 supplied exactly. The rates of losses from all causes are in very fair agreement, but the cordite factory lost many more for reasons of health. This may point to a real difference, owing to the nature of the work being different in the two cases; but more extensive material is necessary to enable one to pronounce a definite opinion.

We can now compare the three tables as wholes. It must be noted that the total rates obtained at the foot of the tables are to be regarded with suspicion; comparisons of them are open to an objection similar to that involved in the use of crude death rates. The numbers at risk at different ages are not in the same proportion in the different populations, for instance 8·8 per cent. of the total exposed to risk is in the service group of Table 6, but 10·4 per cent. in Table 7 and 14·6 per cent. in Table 8. As the rate of loss in every table is much higher in the first few months than in the later months, this causes the comparison of the crude averages to be unduly favourable to the pre-war populations because the latter include proportionally more girls in the later months of service. A better general idea is got from a study of diagrams. In Diagram 1 we have the curve of rates of loss for all causes, and it is seen that on the whole the peace-time rates run higher than the war-time rates for the case and bullet department, and are not very markedly different from the war-time filling department. The losses of the first month are higher in each war-time experience than among the peace-time employees, but this is set off by higher rates among the latter in subsequent months. But an important modification is necessitated by the fact that, before the war, periods of slack trade led to the discharge of girls whose services were not required, and no such factor has been in operation at this factory since the war. Consequently, Diagram 2 is more instructive. From this (paying of course very

DIAGRAM I

ALL LOSSES

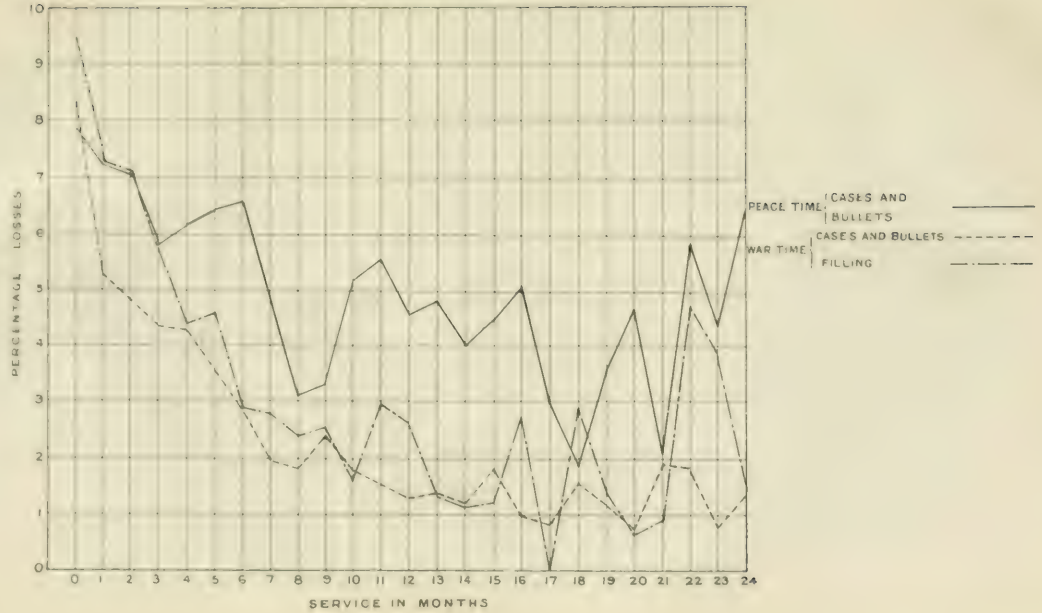
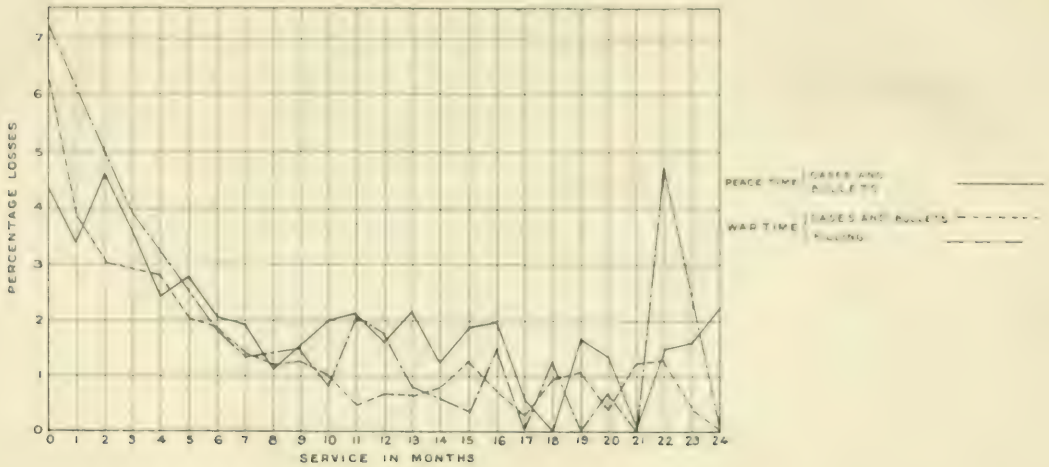


DIAGRAM 2

AVOIDABLE LOSSES



little attention to the erratic percentages for the later months) we may conclude that the trend of events is much the same in the peace time and war time industrial populations. But the suggestion will be made that the class of the population in factories is now very different from what it was before the war, so that an identical rate of loss may mean really a greater steadiness owing to the gross rate being increased by the presence of a percentage of girls who are really unfit, by virtue of temperament or nurture, for the strenuous life of a factory. Some light is shed on this by Table 22, giving the occupations of the employees before engagement. So far as the girls under 18 are concerned, the occupational distributions are similar in peace time and war time experiences. This remark also applies to the group 18-22. No useful comparison can be made in other classes owing to the smallness of the corresponding peace-time populations. Leaving on one side the question whether such differences as *do* appear are significant, in the statistician's sense of the term, it certainly cannot be urged that they are of much practical importance, or that the war-time population is very unlike the peace-time population in respect of the occupational classes from which it has been recruited.

We may now briefly consider points suggested by the detailed tables. Such detailed comparisons will not be pressed far: they involve a proper evaluation of the "probable errors" of the constants compared, and, in view of the fact that most of the differences are absolutely small, it is unprofitable to devote much labour to the rather intricate calculations which such a study involves.

(c) *Losses through Ill Health.*

Less than 300 girls quitted their employment on account of ill health or as the result of some accident during the whole period. The distribution of losses for different lengths of service cannot be satisfactorily elucidated. It does not appear that the differences are significant when one age group is compared with another (Table 24): the crude rate is highest in the filling departments and lowest in the peace-time case and bullet section. Expressed as *yearly* rates the range from 33 to 61 per 1,000 is considerable, and the amount would, *if confirmed on large numbers*, imply that sickness is a somewhat important cause of leaving. But, for the reasons given, I do not think that any such definite inferences should be drawn. The subject will come up for fuller discussion when we consider the whole of the data collected.

(d) *Comparison of Peace Time and War Time Results.*

The diagrams and Tables 6, 7, 8, *supra*, have suggested that, when the losses from all causes are considered, the war time

experience is somewhat more favourable than the peace time results. This is borne out by a more exact test when attention is paid to age. The group chosen was that for ages 18–22, and it was found that the probability of the observed difference being a chance event was small. A good deal of the discrepancy was due to the much higher rates of loss in the months beyond the tenth among peace time workers, but even without that group's contribution to the value of χ^2 the fit is not good.

It has been pointed out above that the advantage of the war time workers is decidedly less when only losses without reasonable cause are considered.

(F) *Comparison of Age Groups*

The test has been applied to the age groups 13–17 and 18–22 of the war-time case hands, and the result is indecisive (Table 24). It is of course possible that some differentiation will be found to exist when we have the advantage of dealing with larger numbers, and more data will be found in subsequent paragraphs. At present it does not appear that any difference which is practically important can be demonstrated.

(G) *Comparison by Occupations*

The general tables, together with the data provided by the factory manufacturing cordite, suggested that the rates of loss in departments handling explosives and chemical substances generally were higher than among the machine hands of the case and bullet departments. A comparison of workers at ages beyond 28 years in the two departments (this age group was chosen owing to its size in the case of the filling hands) neither confirms nor refutes this suggestion. All that can be said is that the differences is not so great that it could not be regarded as a coincidence. Here, again, the data are inadequate for pronouncing a final judgment.

(H) *Summary*

The chief result of the analysis so far described is to establish the fact that the loss of effectives in a well-run cordite munition factory due to theoretically avoidable causes is great. It cannot, however, be taken as proved that the whole of the girls who left without giving any reason for so doing had in fact no sufficient reason.

The loss of effectives, amounting to not less than 10 per cent. and probably to more than 10 per cent. of the original strength, after a period of employment so short that little useful service has been rendered must be contributed to by some or all of the following causes:—

(1) The default of the employee herself, such as caprice, unwillingness to submit to discipline, love of the excitement of change for its own sake.

(2) The fault of the employer as displaying want of judgment in the selection of candidates for employment, the conditions of which are unknown to the applicant but known to the employer.

(3) Similar lack of judgment on the part of the officials of labour bureaux.

No national system of organisation can eliminate these causes of wastage, but it may be possible to diminish them.

So far as the default of the employee is concerned, the State has endeavoured to meet the evil by the introduction of the permit system. I find, however, that difference of opinion exists among factory managers as to the efficiency of this system. It has been urged that since the penal mechanism must be set in motion by the original employer (*i.e.*, if another firm engages the girl without permit, this firm is only penalised when the first employer takes action) it is impossible to take effective action without over-straining the administrative staff.

The other side of the case, viz., the improper selection of applicants, merits further attention. Factory administrators and the officials of labour bureaux indulge in mutual recriminations. On the one hand it has been complained that in a certain national factory the engagement of boys is carried out by the supervisor of the Welfare Department, and that this officer is imperfectly acquainted with the technical conditions and requirements of the shops needing fresh hands, with the consequence that the labour exchange is put to needless trouble owing to the incompleteness of the particulars furnished. On the other hand, cases are said to have occurred in which a labour exchange has sent quite unsuitable candidates to factories situated at long distances from the exchange, with the consequence that both time and railway accommodation have been squandered. It is not, however, the province of this report so much to deal with causes as to contribute to knowledge of effects which stand in need of explanation.

VI.—Study of a Country Factory.

We have now studied the conditions observed in a factory located in the suburban area and will pass to one in very different surroundings. Factory L.7 is in the open country, six miles by rail from the nearest town and still further from any large city. L.7 is indeed very isolated. There is no village in its immediate neighbourhood, no sleeping accommodation and not even a picture palace. A very small number of the workers

can lodge in a village two miles away, but the vast majority must travel at least six miles to and from their work. At present the women work in two eleven hour shifts with weekly change. Forty-eight hours elapse between coming off one shift and entering upon another. There is no Sunday work. All labour is time work, and the rates paid suggest that the total earnings are on the average greater than in L.1 and L.2 although the hourly remuneration is not. The work is divided into that of the concrete and that of the gas-station department; it is therefore roughly similar to that of L.2.

Ample provision is made for the care of workers' health and comfort. In these respects, factory L.7 is probably surpassed by any other in the country.

The arrangements are controlled by a matron, who is a trained nurse, having under her four or five forewomen specially appointed (never promoted from among the workers), who have charge of the mess rooms, kitchens and changing rooms. Special attention is directed to the catering arrangements, the governing principle being that an ample supply of nourishing, well-cooked food must be provided for women at work. Employees are obliged to take advantage of these arrangements, nobody being permitted to bring food into the factory.

All the workers receive dinner and tea (which latter meal is of a substantial character) for 10*d. per diem*, which sum is deducted from wages. Special trams run to the factory to convey workers to and from their places of employment; in these the women travel free of charge.

Engagements are effected through the labour exchanges of the two towns least remote from L.7, and no direct applications for work are entertained. Any woman absent for more than two days without communicating with the management is automatically discharged. *But in practice all these cases are followed up and the sick visited.*

The rate of wages has not been increased (except in the case of charge women) since L.7 was opened, roughly twelve months ago (written in February 1917). At present (i.e. when the data were collected) there are approximately 900 women at work.

Tables 25–28 contain the analytical results which are strictly comparable with those above, and may be contrasted with the tables relating to L.2. For women over 28 the rates of loss from all causes in the first month of service are much the same in the two factories, but those for no sufficient reason are half as many again in L.2. In all other months at this age, and for all months at other ages, the rates are very much lower in L.7 than in L.1 or L.2.

As will be seen from Table 29, if the rates of loss found in L.2 had applied to the present factory, there would have been

227 losses; actually there were 79, or little more than a third of the expected number.

Table 30 gives the distribution of the employees by previous occupation, and brings them into comparison with those of L 2 (war time employees). It will be seen that the distributions are by no means identical. Unfortunately the age groups over 28 cannot be properly compared owing to the large proportion of women from L 2 the previous occupations of whom are unknown. In age group 23–27 the domestic servants, laundry hands and shop assistants are in considerable excess at L 7, and the factory girls in defect. The same remark applies to the under 22 group where, also, the girls not previously engaged in directly paid work (that is, those said to have done "household work") are only half as numerous as in L 2.

This is a very interesting fact, and the question arises whether (*a*) the women who have had no previous experience of factory life are really less likely to remain steadily at work than old factory hands, or (*b*) whether they *are* less likely to remain, but the conditions of employment are so favourable at L 7 as more than to counter-balance the initial instability of the population. Evidently the ideal plan statistically is to tabulate losses by previous occupation, but even in L 1 and L 2 the data are hardly numerous enough to allow of this being done with any hope of reaching averages which would bear statistical scrutiny, and they are of course much too scanty at L 7. This process must therefore be deferred until further data have accumulated. It is prudent to suspend judgment on the point. The investigation does, however, disclose facts of practical importance at the present time. We see that the losses of a factory, which is by no means in the rear rank of existing munition factories, are nearly three times those of another factory the conditions of which, although good, can hardly be considered an ideal unattainable elsewhere. Now we cannot say definitely that these better conditions are the cause of the advantage: it is arguable, in view of the previous occupational distributions, that what has really happened is that the country factory has drawn its labour from country people, and that these are less prone to change than urban girls. But, if this *is* the case, it follows that special efforts should be made to recruit the country girls for munition factories, and wherever possible, to extend the factories operating in provincial towns of the second or third rank, or in purely country districts. It should, on this hypothesis, be considered whether the superior transport facilities of the great cities really compensate for the waste of time and effort involved in numerous short term engagements and re-engagements. Of course, if this alternative explanation should prove on further examination to be unnecessary, then a rapid levelling up of the hygienic conditions to the standard established in the factory under notice will suffice to steady employment.

One point must at least be regarded as definitely established, viz., that existing rates of loss in many factories are unnecessarily high, and that so long as they continue the effective mobilisation of labour for national service has not even been approximately realised. When expressed in terms of the whole munition making female population the avoidable losses must amount to many thousands.

Thus far we have examined in detail two factories, the extreme characteristics of which contrast. We must now study one the circumstances of which are, in some measure, intermediate between two extremes.

VII.—Study of a Midland Factory.

The requisite data were obtained from a factory in a midland industrial city, manufacturing and filling fuses for 18-pdr. shells. The establishment is organised into two branches, one manufacturing the fuses, the other loading them, hereafter called L.4 and L.5. In both sections the general hygienic conditions of the shops is excellent. The immediate surroundings are of the usual type one associates with the inner suburban zone of a manufacturing town. The factory is at some distance from the centre of the town, the neighbourhood is crowded, and there is much difficulty in obtaining lodgings. Cheap restaurants or tea shops are not numerous, perhaps less so than in corresponding metropolitan areas. To meet these inconveniences, the firm has provided canteens and residential hostels. The former are well conducted, and the arrangements for serving and preparing meals cleanly and efficient. The proportion of women who actually purchased their meals in the canteens was not, so far as simple observation revealed, very large, and there seemed to be an impression that the accommodation was insufficient.

The residential hostels, which housed a larger proportion of the women employed in L.5 than of those in L.4, were provided with separate canteens. Here also, practically no complaints which refer to temporary occurrences, the smallness of the accommodation seems to have been the principal defect.

This factory employs the whole-time services of a qualified medical woman, and all women admitted to work in the filling section are subjected to a preliminary medical examination.

For purposes of inquiry the records kept proved to be similar to those made in L.2, L.1 and L.7, with the rather unfortunate exception that no particulars were available as to the previous occupations of the women.

In a general way, it may properly be inferred that the welfare system was inferior to that of L.7 but superior to that of factories L.1 and L.2. As to material differences between L.4 and L.5 in addition to the points above noted with reference to preliminary medical examination and the fact that a larger proportion of

the women in L.5 resided in the hostels, it is to be mentioned that the rate of payment was higher in its shops.

The period statistically investigated covers engagements effected between 1st January, 1916, and 1st December, 1916, and refers to 2,584 engagements in the filling and 2,424 in the making shops. The data have been handled precisely as those discussed above, with one exception. In L.1 and L.2 the (very small) number of women who left on grounds of medical unfitness as distinct from actual illness, were classified under the general heading "left for 'sufficient' reason." In this factory the numbers, being relatively numerous, were scheduled separately. The nine tables contain the full analytical results. We will consider first L.4 (Tables 31-35). The differences between the rates for different age groups, whether statistically significant or not, are absolutely small and need not detain us; we may compare the table for all ages with that of L.1. So far as the rate of loss from all causes is concerned the difference is not at all striking. The present factory has the advantage in the first month but loses it afterwards, with the result that the numbers lost by the conclusion of the fifth month from entrance are not very different in the two cases. The detailed distribution of losses is not, however, the same, the other factory had consistently higher losses for "no known reason," the present lost more for "health" reasons, even apart from the elimination of workers as medically unfit. As there is no reason to suppose that this factory is in any way more unhealthy than the former one, the explanation must be, either that a large proportion of those who left in the other factory without giving any reason did so for reasons of health, or, alternatively, that the health losses in the present case were really losses without adequate reason, the bad health being merely an excuse. The latter alternative is perhaps the more probable, because, in view of the presence of a whole-time medical officer, it seems likely that most of the genuine cases of illness will fall under the medical unfitness column which, it will be noted, does not differ much in relative magnitude from the health column of the earlier table. If, however, this explanation is not accepted, it would seem that the health losses are rather serious, amounting to nearly 1 per cent. *per mensem* throughout the table, over and above the medical rejection of nearly ½ per cent. *per mensem*.

Looking at the results generally we may properly assimilate the experience with that of the first factory, and contrast it with that of factory L.7.

Passing now to L.5 (Tables 36-40) the rates are seen to be consistently much lower than in L.4. This difference is seen particularly in the sub-section of losses for no known reason, the health losses not being greatly less than in the other factory. At first this factory seems to yield better results than even L.7, but this first impression is not altogether borne out by further study. So far indeed as the first month is concerned this factory

...ome better, but its rates of loss in subsequent months are consistently high—higher than in the other establishment, with the result that the numbers who have left by the end of the fifth month form 12·6 per cent. of original entrants as compared with 10 per cent. in the previous case. On the basis of the numbers at risk it is not practicable to assert any superiority of one over the other. The evident superiority of the L.5 C over L.4, which is too distinct to be properly attributable to chance errors, needs explanation. Three factors which have probably contributed are (1) the preliminary medical examination of entrants, which ...ects out many of the unfit; (2) the higher proportion of women ...rived from long distances and specially housed under some ...pervision; (3) the higher rate of payment. Some further light ...ould be thrown upon the relative importance of these factors ...ld we if we had a knowledge of the occupational distribution ...f employees before engagement, and if we had accurate data as ...to net earnings for the two groups. Neither *desideratum* being ...vailable we must leave the possible explanations without ...omment. But the general result, viz., that the factory *as a ...hole* (i.e. L.5 and L.4 *together*) is better off than L.1 and L.2 ...nd worse off than factory L.7 in the matter of wastage, while it ...occupies a similarly intermediate position between the two factories in welfare efficiency is to be remembered when the general welfare account comes to be balanced.

VIII.—Study of Factories on Heavy Work.

I now turn to a group of three factories, also situated in a provincial manufacturing city but doing rather different work from that which has so far come under our notice.

These three factories are all manufacturing projectiles. H.3 produces 4–6 inch shells, H.2 6–9 inch shells, and H.1 9–15 inch projectiles. The H.1 workers are on time wages, the remainder on piece-work. Up to August 1916, eight hour shifts were worked in all three; since then H.3 has used twelve hour shifts.

Women employed in these factories are for the most part recruited in the district, and no residential hostel have been provided. The factory canteens are good, while two of the factories themselves are well constructed. The third (H.2) has not been considered altogether satisfactory from the hygienic standpoint.

In Tables 41–53 I present statistical analyses, which are comparable with those prepared for the other factories. Table 54 similarly provides information respecting previous occupation. A consideration of Tables 41–53 reveals the fact that H.1, H.2 and H.3 do not, with the exception of the age group 18–22, compare favourably with any other factory so far discussed in this report. Great caution must be exercised in drawing conclusions, because the absolute numbers of employees are small and on this account I abstain here from any attempt to differentiate H.1, H.2 and H.3 one from another. That the rates of

loss at ages above 22 are significantly greater than in the first age group (no statistics are provided for girls under 18 as the number was quite insignificant) is I think established. I have applied the test mentioned above (p. 16) to the comparison of rates of loss in the age groups 18-22 and 23-27 for H.1, H.2 and H.3, grouping together the exposed to risk in month 9 and subsequent months. The probability that the observed difference is a mere chance is, by this test, very small, less than 6 in 10,000. This test is not, as remarked in the appendix, altogether satisfactory, having been devised for a slightly different kind of statistics, viz., death-rate at ages of ordinary vital statistics, but is acceptable as a rough and ready criterion.

If the separate tables are carefully examined it will appear that the unusually heavy losses are seriously contributed to by the "ill health" and "other sufficient reasons" columns, a fact which suggests that we are really dealing with an evil for which the employees themselves are not responsible. I am, of course aware that the accuracy of statements purporting to describe the grounds for leaving is not likely to be of a high order. But, simply regarded as indices, these classifications are I believe of real value. It would be a gratuitous assumption to suggest that the proportion of untruthful persons in one factory is likely to differ sensibly from the percentage in another. I think, therefore, that these three factories offer a problem in need of an objective solution. The record of previous occupations does not furnish this. Unfortunately a large proportion of the women have had no entry made upon their cards as to the nature of the previous employment, but, so far as appears (Table 54) the percentage of industrially employed women is greater than in L.1, L.2 or L.7. We should expect this to be the case in a large manufacturing city using local labour, and it is possible that this contributes to frequent changing of employment, there being good opportunities to obtain another place. Further than this we can hardly go.

The next fact to be considered is that, while the women undergo no preliminary medical selection their work is appreciably heavier than in the fuse and cartridge factories, which provided so much of our other material. The large percentages of women, especially older women, who gave up work on alleged physical grounds are clearly consistent with the view that we have to deal with an occupation which is on the whole unsuitable for such women, so that both a preliminary medical examination and also perhaps a re-distribution of female labour as between factories of different types might solve the problem. I do not, however, think that any such far reaching conclusion can properly be based upon data obtained from a single group of factories. It is necessary to widen the scope of this inquiry, and to look upon the results here communicated as suggestive of what such a wider inquiry might contribute to our practical knowledge.

IX.—General Comparison of Light and Heavy Factories.

(A) *Introductory.*

The reader has now been brought to the point at which I arrived on May 2nd, 1917. There seemed to be a considerable difference between the wastage of women workers in factories on relatively light physical work and in those engaged upon more laborious tasks; but this conclusion rested upon a comparison between several "Light" and only a single group of "Heavy" factories. It was accordingly decided to investigate several more "heavy" factories, and also one or two "light" factories. The "heavy" group comprises one very large controlled establishment making projectiles, eight national projectile factories and one national shell factory; the representatives of the "light" class were an explosives supply factory and a national cartridge shop.

The data have been distributed into 55 tables which, owing to curtailment of paper supplies and expense of setting, cannot be reproduced here. In making comparisons certain fallacies exist which cannot be completely guarded against but may be minimised.

(B) *Sources of Error.*

All the establishments previously considered were such and, from the point of view of time period investigated,* so chosen that variations of production or programme did not complicate the comparisons. When we so extend our data as to include as many factories as can furnish *statistics* (which is what was done with respect to national projectile factories) we cannot pick and choose, and may be dealing with a period during which, owing to changes of constructional programme, large numbers of hands were discharged. This does not of course affect the rates of loss for insufficient reasons, provided the records are properly kept, because women discharged on account of changes of programme are entered under the heading "left with sufficient reason."

* A point in the method of reduction which may seem to the reader arbitrary, is that we restrict the analysis to persons who *entered* during the period to which the losses relate. Thus when we took, say, the losses of 1916, we only used those relating to entrants during that year, so that we could have to persons exposed to risk for more than a year. It may be asked why did we not tabulate *all* persons, irrespective of their date of engagement, who were exposed to risk during the chosen period, bringing for instance a person engaged a month before the period started into the "exposed to risk" column of the second month (not of course into the first month) and so on. The advantage would be to increase the numbers upon which the rates of leaving for later months are based; the disadvantage is that the employees from an earlier period of service may (under the rapidly changing industrial conditions) have been subject to a process of selection different from that in operation during the period chosen. This disadvantage, combined with practical difficulties of unsulting older records of engagement, has determined the actual procedure.

But it might greatly affect the total rate of leaving, and a comparison of such rates might therefore be gravely misleading. Thus the fact of one factory having a higher rate of loss than another might only mean that the constructional programme of the former had been varied during the period under review. As mentioned, the comparison of rates of leaving for no known reason or those due to ill health would be less affected by this disturbance were the records accurate. But no *ex post facto* investigations, as these necessarily are, can proceed on the assumption that the list of those who left without recorded reason does not include a proportion of losses consequent upon a change of programme. In one or two of the factories (*e.g.*, H.4) it was possible to select a period in which no changes of programme or difficulty in securing supplies of raw material complicated the analysis, and I always endeavoured to secure suitable periods. This endeavour may not, however, have been always successful.

Another theoretical source of error is the fact that the period studied has not been the same in all factories. Consequently, in combining the data into a general summary we are bringing together observations which are not strictly comparable, for they do not relate to contemporaneous events. This error was unavoidable, but, as the periods available are not in fact widely separated, in particular, there has not been a systematic choice of more recent periods for H. factories as a whole, it is improbable that the admitted heterogeneity introduces a practically important error. The next point arising is the broad classification into L. and H. groups. In all but two instances there is no doubt as to the appropriate class: the L.'s were engaged in rifle cartridge, fuse making or filling work, while the H.'s were on heavy projectile manufacture. The borderland cases are L.6 and H.5, where smaller shells were made. Hence both might have been grouped under H. or L. The considerations determining the actual classification of these intermediates were that L.6 conformed in several other respects to the circumstances of L.8, the classification of which was free from doubt, while similarly H.5 had points of resemblance to H.6. In any event, the classification being doubtful, an allocation of one factory to each group is appropriate. On the whole there is no doubt that the actual amount of muscular effort required by a working day of the same length is greater in factories of class H. than in those of class L. Of course variations exist as between different factories within the same class, but the general difference is of the kind indicated.

We can now review the influence of different factors upon the rates of loss.

(c) *Influence of Age.*

This matter has been discussed in detail above in connection with individual factories. A general survey is provided by Table 74 (in this table the under 18 group is not given because

few of the H. factories employed sensible numbers of girls under 18). The figures prefixed with the signs ± are the probable errors of sampling computed by a method described in the Appendix. These probable errors are to be regarded as mere rough approximations; differences falling within three times the limits of these errors may be disregarded; on the other hand greater deviations cannot be decisively asserted to lie outside the real limits of feasible sampling errors. The survival rates which are compared are the percentages of entrants still at work at the conclusion of the third month from entrance (*i.e.*, after the losses of months 0, 1 and 2 have been allowed for). This limit has been taken as covering reasonably probable variations of registration, and also as corresponding to the extreme period of novitiate within which the average entrant has not attained her best level of productive power.

It will be seen that the survival rates diminish with age almost invariably among the H. factories, while this is not so in the L. group. Taking the combined data of the two groups we reach Table 75. We find that the age group 18–22 is in a more favourable position than either of the later age groups among H. employees, while the differences observable in the L. group are almost within the sampling errors of the determination and not practically important.

The older women differ from the younger, not only in age but also in that a larger proportion of them are married. Unfortunately we have not statistics of civil state for the whole of the factories, but the data of Table 78, relating to three factories, sufficiently illustrate the point. It appears that the double handicap of age and home duties is insufficient to diminish appreciably the resisting powers of the older women, so far as light physical labour in factories is concerned, when we pass to a heavier type of work this ceases to be true. The general analysis confirms the surmises based upon the particular comparison of factories discussed above. We may conclude that, from the point of view of wastage, the recruitment of women over 22 for H. factories is relatively disadvantageous.

(D) *Influence of Type of Work.*

In continuation of the above comparison we may bring beside one another the same age classes of different factories. It will be seen that the wastages are on the whole smaller throughout the L. group at each age than in the H. group (see Tables 61–72 and Tables 74–5). At ages 18–22 the difference is, however, small. At ages 23–27 and over 28 it is sufficiently obvious. At the same time I draw conclusions with some reserve. One at least of the H. factories (H 8), showing a very heavy rate of loss at all ages, did not furnish data which I regard as entirely satisfactory.

On the whole, however, the general impression is confirmed by the increase of wastage with age among nearly all H. factories, and the failure of L. factories to exhibit this.

A specially interesting comparison is between H.6 and L.7 both of which are situated in the same part of the country and conform to the highest standards of general management. L.7 is a national filling factory handling T.N.T.; H.6 is a national projectile factory. The three months' wastages are not significantly different at ages 18–22 nor at ages 23–27. At ages over 28 the filling factory loses appreciably fewer women than the projectile factory. In this comparison all factors are constant save the type of work, and the inference seems legitimate that labour in projectile factories is really less suitable for older women.

(E) *Discussion of Losses from Ill Health.*

I cannot attach much importance to the recorded incidence of sickness for reasons set out above—the data are not attested by medical evidence and may be no measure of the true incidence of sickness upon munitions workers. Still, it is necessary to call attention to the results. From general Table 59 we learn that among nearly 37,000 women under observation for at least a month, illness or medical unfitness is given as the cause of leaving 1,651 times. A survival table showing the wastage which would have occurred had sickness alone been responsible for leaving is provided in Table 76. It appears that the losses from ill health are practically the same at all ages in L. factories while they increase but not uniformly after age 22 in the H. factories. The girls under 23 have fewer sickness losses in the H. than in the L. factories. An explanation which suggests itself is the differential incidence of toxic jaundice and allied conditions upon younger women in filling factories. This is not, however, the real explanation, for it is unsubstantiated by a comparison of Tables 79 and 80, which record the particulars for age groups 18–22 in the most accurately comparable filling and projectile factories. In those tables it will be seen that the sickness losses of the filling factory are not higher than those in the projectile factory.

(F) *Local Variations.*

I have already called attention to the wide local divergences in commenting on special factories in detail. I have suggested that some part of the explanation is to be found in differences in the efficiency of welfare supervision. I cannot say that this explanation is demonstrably correct, but the contrasting conditions of L.7 and L.5 on the one hand with those of L.1, L.2, L.3 and L.8 on the other are of interest. It might not unreasonably be suggested that any factory which loses more than 20 per cent. of its entrants within three months should institute a special enquiry into the reasons. Naturally, in some cases, it will be found that quite sufficient reasons exist. Thus the heavy losses of L.6 are explicable on the ground of great difficulties in securing housing accommodation, but this explanation will not cover all cases.

(6) *Hours of Labour and Wastage.*

Table 77 contains particulars of hours of labour brought into comparison with rates of wastage at ages 28 and over (these latter rates being, I think, sensitive indices of change). It is evident that the two variables are not closely connected. It is true that in the two factories with the longest working weeks the survival rates are low, but the highest survival rates are not found in the factories working the shortest hours; expressed as a correlation we have $r = -.05 \pm .16$, to which no significance attaches.

The comparison throws no new light upon the connection between industrial wastage and length of hours. Of course, it does not demonstrate that no important connection exists. The data are unsuitable for an exact analysis.

(7) *Relation of Wastage to Previous Occupation.*

The facts elicited are shown in the various tables, and it would be of interest to determine whether wastage varies among recruits from different classes of industry. I am of opinion that the available data are inadequate for such an inquiry. The returns of no single factory are numerous enough to allow of the necessary sub-division being undertaken with a real hope of arriving at statistically significant results. A combination of the totals is impracticable, since the proportions of employees whose previous industrial history was unrecorded vary from factory to factory. Altogether, apart from this, it is improper to combine the data because geographical factors necessarily influence the frequency with which particular occupations are drawn upon. These geographical factors, to which I alluded above, are perhaps of as much importance as previous occupation. All the factories studied in this report, except L.7, are situated in purely industrial districts. I think it would be well to examine the records of some wartime factories which have been erected in towns not normally industrial in character.

X.—General Conclusions.

The primary object of this inquiry was to ascertain the actual extent of industrial wastage among women employed in munitions factories, and this object may, I think, be deemed to have been attained. It is true that the analysis covers but a small proportion of the total number employed in munitions industries, but the actual scope of the inquiry relating to nearly 40,000 employees in 18 representative factories is sufficient to entitle the sample to be regarded as typical of existing conditions.

The general sense of the later observations is concordant with that of the fully analysed material provided by factories discussed in the earlier sections of this report and confirms the inferences provisionally drawn from that material. Some of the minor conclusions are, as noted in the text, subject to a

measure of uncertainty and are therefore provisional, but broader conclusions cannot be contested.

In the first place, it has been proved that the magnitude of the problem of wastage is considerable, that there is much discontinuity of employment, even in the best-managed factories, which must prejudicially affect output.

In the second place, it has been shown that much of this wastage is inexplicable or at least unexplained. The greatest proportion of the losses is unaccounted for. Of a total number of 11,005 women who left, 6,697 gave no reason for so doing or a frivolous reason. This is not a satisfactory state of affairs. In the existing shortage we can ill afford to allow the ranks to be depleted without sound reason being rendered. There is no panacea for the disease, but there is one promising remedy: this is organised welfare work. We have already seen that in factories with well-organised welfare departments the wastage unaccounted for is below the average, even if we must hesitate to bring the two things into the simple relation of cause and effect. The experience of such factories as L.7 is instructive in this respect. No claim is set up that the statistical inquiry has brought to light an unknown truth in this connection; but it has suggested an approximate measure of the magnitude of the effect. When we compare the varying rates of loss in different factories doing similar or identical work and remember what a large proportion of these losses is debited to the unexplained group, we realise the extent of the field open to welfare work. What is needed is no mere paper system of stringent interrogatories administered to the women who leave. Such a system might diminish the number of women falling within my N.S.R. class, but whether it would do more than stimulate the operative's ingenuity in inventing plausible excuses is doubtful. Intelligent and sympathetic "following up" of absentees is more likely to produce good results than any addition to the mass of questionnaires and forms which already encumber the tables and burden the lives of factory officials.

In the third place, it appears that the general strain of factory life in itself is not worse borne by older than by younger women, even in factories engaged upon chemical work which has often been associated with special danger to the health of certain individuals. On the other hand, when the general strain of factory conditions is combined with more than a very moderate degree of actual physical work, women over 23 come less well through the ordeal. The difference is not indeed catastrophic, but it is distinct enough to make an attempt at systematic recruiting of the older women for the physically lighter labour and of the younger women for the more strenuous tasks worthy of practical attention. It is to be noted that the nature of the distinction is not the mere truism which a hasty reader might suppose. No statistics are necessary to prove that women really in the decline of life are unsuitable for heavy labour. The

change occurs during physical maturity, and the most plausible explanation is that the older women, of whom a larger proportion will be married and have young children than of the girls under 23, have not sufficient reserves of energy to meet the double demand made upon them.

I consider that the above inferences are fully established by the evidence submitted. The many detailed hypotheses and suggestions as to various points are, I believe, worthy of consideration and are on that ground submitted to the reader's judgment. Finally, it is my pleasant duty to acknowledge the valuable assistance rendered by my co-workers, Miss Thompson, Miss Wilcox and Miss Woods, upon whom has fallen nearly all the labour of collecting and much of the labour of analysing the data. I have also gratefully to acknowledge the financial assistance of the Medical Research Committee which enabled me to secure clerical help at the beginning of the inquiry.

APPENDIX I. TABULAR MATTER

TABLE I.

Losses and Gains in Munition Factory A.1 (1916).

June	1,340	[illegible]	38	34	1,113
July	1,651	348	48	87	1,113
August	1,181	563	67	230	1,297
September	1,308	478	53	43	1,297
October	1,146	1,054	50	158	1,297

TABLE 2 *Female Workers, Cordite Factory* (1916)

Length of Service	28th Feb. to 28th March		28th March to 28th April.		28th April to 28th May		28th May to 28th June.		28th June to 28th July.		28th July to 28th Aug.		28th Aug. to 28th Sept.		Totals.	
	I.H.	O.C.	I.H.	O.C.	I.H.	O.C.	I.H.	O.C.	I.H.	O.C.	I.H.	O.C.	I.H.	O.C.	I.H.	O.C.
Under 1 month	10	6	4	3	3	20	3	5	0	4	14	14	4	3	38	55
1–2	4	10	6	7	1	4	0	4	0	2	2	1	10	13	23	41
2–3	2	6	4	10	5	5	4	2	2	1	3	3	5	5	25	35
3–4	0	0	2	3	4	11	1	6	2	0	3	3	3	10	15	33
4–5	0	1	1	1	1	3	2	7	0	8	1	5	8	4	13	29
5–6	0	0	1	1	1	1	3	6	0	9	2	5	2	2	9	24
6–7	1	0	1	0	1	1	1	3	0	2	5	1	1	2	10	12
7–8	0	1	2	0	0	0	1	1	1	3	0	0	3	5	7	10
8–9	0	0	0	1	0	3	0	1	0	1	2	0	0	1	2	7
9–10	0	0	0	0	0	2	0	1	1	2	1	0	1	6	3	11
10–11	0	0	0	0	0	0	0	0	0	0	1	2	0	3	1	5
11–12	0	0	0	0	0	0	0	0	0	1	2	3	1	1	3	5
Totals	17	24	21	28	16	50	15	26	6	36	36	10	38	55	149	267

TABLE 3.—*Male Workers, Cordite Factory* (1916).

Length of Service.	28th Feb. to 28th March.		28th March to 28th April.		28th April to 28th May.		28th May to 28th June.		28th June to 28th July.		28th July to 28th Aug.		28th Aug. to 28th Sept.		Totals.	
	I.H.	O.C.	I.H.	O.C.	I.H.	O.C.	I.H.	O.C.	I.H.	O.C.	I.H.	O.C.	I.H.	O.C.	I.H.	O.C.
Under 1 year	8	8	1	10	3	2	1	2	6	8	9	7	3	3	28	41
1–2	2	2	3	6	5	6	4	5	3	1	3	1	3	3	24	18
2–3	1	1	1	1	1	8	0	7	0	3	0	1	2	4	5	25
3–4	2	1	0	6	0	4	3	8	2	1	0	1	2	0	11	21
4–5	0	0	1	0	2	4	2	6	0	4	0	1	0	2	5	17
5–6	0	1	0	0	1	2	0	2	1	2	1	4	0	1	3	12
6–7	0	0	0	1	0	2	1	3	1	5	0	2	1	0	3	13
7–8	0	0	0	1	1	0	0	0	0	4	0	0	2	2	3	7
8–9	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	3
9–10	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	1
10–11	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
11–12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Totals	14	13	6	29	13	28	11	34	13	29	13	18	13	15	81	158

TABLE 4.

Cordite Factory.

Period	Men.		Women.	
	Joined.	Left.	Joined.	Left.
1915				
July 19th—Aug. 27th	16	59	162	45
Aug. 28th—Sept. 27th	44	18	153	33
Sept. 28th—Oct. 27th	66	16	49	22
Oct. 28th—Nov. 27th	75	41	16	30
Nov. 28th—Dec. 27th	123	26	69	18
Dec. 28th—Jan. 27th ...	108	37	247	45
1916				
Jan. 28th—Feb. 27th	114	37	369	117
Feb. 28th—Mar. 27th	131	28	127	34
Mar. 28th—April 27th ...	89	31	62	38
April 28th—May 27th	82	49	182	70
May 28th—June 27th	33	43	16	54
June 28th—July 27th	94	48	144	48
July 28th—Aug. 27th	72	32	99	88
Aug. 28th—Sept. 27th	68	32	84	113
Total ...	1,112	498	1,773	771

TABLE 5.

Rates of Loss (Terminating Claims) Factory.

TABLE 6.

Taking effect 1st July (or Jan.) 1914—30th June 1918.

Length of term, in months	Number originating	Expiries. Lost. By death	Expiries. Lost. By [illegible]	Expiries. Lost. Total	Discontinuances. By death	Discontinuances. By [illegible]	Discontinuances. By [illegible]	Total
0	1,116	2	37	39	11	2	1	14
1	1,102	2	21	23	11	2	1	14
2	1,065	1	18	19	11	2	1	14
3	1,032	1	9	10	10	2	1	13
4	1,009	2	18	20	11	2	1	14
5	975	2	9	11	10	2	1	13
6	951	2	17	19	11	2	1	14
7	918	2	9	11	10	2	1	13
8	894	2	9	11	10	2	1	13
9	870	2	9	11	10	2	1	13
10	846	2	9	11	10	2	1	13
11	822	2	9	11	10	2	1	13
12	798	2	9	11	10	2	1	13
13	774	2	9	11	10	2	1	13
14	750	2	9	11	10	2	1	13
15	726	2	9	11	10	2	1	13
16	702	2	9	11	10	2	1	13
17	678	2	9	11	10	2	1	13
18	654	2	9	11	10	2	1	13
19	630	2	9	11	10	2	1	13
20	606	2	9	11	10	2	1	13
21	582	2	9	11	10	2	1	13
22	558	2	9	11	10	2	1	13
23	534	2	9	11	10	2	1	13
24	510	2	9	11	10	2	1	13
Total	[illegible]	42	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

* In this and subsequent tables the column headed "Number Originating" gives the number of persons assumed to make a beginning for each month of duration, i.e., 1,116 persons through the last month to have passed the first month.

Factory L.I.

Table 7.—*All Ages (4th Aug., 1914—1st Dec., 1916).*

Length of time, in months.	Number employed.	Numbers Left.				Percentages.			
		Bad health.	Other sufficient reason.	No reason, or insufficient reason.	Total.	Bad health.	Other sufficient reason.	No reason, or insufficient reason.	Total.
0	4,479	26	59	289	374	·580	1·317	6·452	8·350
1	3,989	13	43	154	210	·326	1·078	3·861	5·264
2	3,719	18	48	113	179	·484	1·291	3·040	4·825
3	3,412	14	36	99	148	·410	1·056	2·902	4·338
4	3,084	11	36	86	131	·356	1·167	2·789	4·248
5	2,774	10	45	54	99	·360	1·620	2·019	3·569
6	2,520	10	18	43	71	·397	·595	1·705	2·817
7	2,297	2	20	23	45	·087	·871	1·001	1·959
8	2,150	3	11	24	39	·139	·512	1·116	1·814
9	1,967	11	13	24	48	·559	·660	1·220	2·440
10	1,791	4	16	18	38	·223	·838	1·005	2·067
11	1,641	2	15	8	25	·121	·429	·196	1·548
12	1,421	3	6	9	18	·211	·422	·633	1·267
13	1,292	3	7	8	18	·232	·542	·619	1·393
14	1,126	0	3	9	13	·000	·266	·799	1·155
15	995	1	5	12	18	·100	·503	1·206	1·809
16	843	0	2	6	8	·000	·240	·719	·959
17	749	1	1	2	6	·134	·134	·267	·801
18	648	1		6	10	154	·308	·926	1·543
19	586	0	1	6	7		·172	1·029	1·201	
20	574	1	1	2	4	·174	·174	·380	·778
21	429	0	3	5	8		·234	1·191	1·995
22	317	1	1	4	6	·315	·315	1·262	1·893
23	266	0	1	1	2		·376	·376	·752
24	225	1	2	0	3	·444	·889		1·333
Totals	43,158	147	561	1,021	1,729	·341	·813	2·365	3·526

Factory L.I

Table 8.—*All Ages (4th Aug., 1914—1st Dec., 1916).*

Length of time, in months.	Number employed.	Numbers Left.				Percentages.			
		Bad health.	Other sufficient reason.	No reason, or insufficient reason.	Total.	Bad health.	Other sufficient reason.	No reason, or insufficient reason.	Total.
0	2,755	15	48	198	261	·544	1·743	7·191	9·474
1	2,264	24	43	93	160	1·060	1·899	4·107	7·066
2	2,009	15	26	101	142	·746	1·294	5·027	7·067
3	1,667	4	25	65	94	·240	1·500	3·900	5·640
4	1,452	6	10	44	60	·413	·688	3·030	4·132
5	1,173	7	16	23	46	·597	1·364	1·961	3·922
6	887	1	9	18	28	·113	·901	2·029	3·156
7	698	3	10	12	25	·430	1·433	1·719	3·582
8	585	3	5	11	19	·513	·855	1·880	3·248
9	473	3	4	10	17	·634	·846	2·114	3·594
10	327	2	1	2	5	·612	·306	·612	1·530
11	242	2	0	11	13	·826	·000	4·545	5·372
12	156	2	2	8	12	1·282	1·282	5·128	7·692
13	101	1	1	3	5	·990	·990	2·970	4·950
14	109	0	2	2	4	·000	1·835	1·835	3·670
15	80	1	1	1	3	1·250	1·250	1·250	3·750
16	80	0	1	4	5	·000	1·250	5·000	6·250
17	62	0	0		0	·000	·000	·000	·000
18	42	1	3		4	2·381	7·143	·000	9·524
19	31	1	2		3	3·226	6·452	·000	9·677
20	15	0	0	1	1	·000	·000	6·667	6·667
21	11	0	1	0	1	·000	9·091	·000	9·091
22	8	0	0	1	1	·000	·000	12·500	12·500
23	8	0	1	2	3	·000	12·500	25·000	37·500
24	6	0	1	0	1	16·667	·000	·000	16·667
Totals	18,700	95	217	639	951	·508	1·160	3·416	5·084

Factory L 1

Table 9.—*Ages 13-17 (1st Jan., 1911—4th Aug., 1914).*

Length of Time in months	Number employed	Numbers Left				Percentages			
		Died	Other causes	No reply	Total	Died	Other causes	No reply	Total.
0	36		36		36		8·33		8·333
1	108	1	8	1	10	0·93	7·41	0·93	9·26
2	86	1	6	1	8	1·17	6·98	1·16	9·30
3	86	1	3	1	5				5·81
4	86	2	3	1	6	2·33	3·49	1·16	6·98
5	86	2	3	1	6	2·33	3·49	1·16	6·98
6	86	2	3	1	6	2·33	3·49	1·16	6·98
7	86	2	3	1	6	2·33	3·49	1·16	6·98
8	86	2	3	1	6	2·33	3·49	1·16	6·98
9	86	2	3	1	6	2·33	3·49	1·16	6·98
10	86	2	3	1	6	2·33	3·49	1·16	6·98
11	86	2	3	1	6	2·33	3·49	1·16	6·98
12	86	2	3	1	6	2·33	3·49	1·16	6·98
13	86	2	3	1	6	2·33	3·49	1·16	6·98
14	86	2	3	1	6	2·33	3·49	1·16	6·98
15	86	2	3	1	6	2·33	3·49	1·16	6·98
16	86	2	3	1	6	2·33	3·49	1·16	6·98
17	86	2	3	1	6	2·33	3·49	1·16	6·98
18	86	2	3	1	6	2·33	3·49	1·16	6·98
19	86	2	3	1	6	2·33	3·49	1·16	6·98
20	86	2	3	1	6	2·33	3·49	1·16	6·98
21	86	2	3	1	6	2·33	3·49	1·16	6·98
22	86	2	3	1	6	2·33	3·49	1·16	6·98
23	86	2	3	1	6	2·33	3·49	1·16	6·98
24	86	2	3	1	6	2·33	3·49	1·16	6·98
Total	2,064	35	110	24	169	1·69	5·33	1·16	8·18

Factory L 1

Table 10.—*Ages 18-22 (1st Jan., 1911—4th Aug., 1914).*

Length of Time in months	Number employed	Numbers Left				Percentages			
		Died	Other causes	No reply	Total	Died	Other causes	No reply	Total.
0	36		1		1		2·78		2·78
1	108	1	11	1	13	0·93	10·19	0·93	12·04
2	86	1	4	1	6	1·17	4·65	1·16	6·98
3	86	1	3	1	5	1·16	3·49	1·16	5·81
4	86	2	3	1	6	2·33	3·49	1·16	6·98
5	86	2	3	1	6	2·33	3·49	1·16	6·98
6	86	2	3	1	6	2·33	3·49	1·16	6·98
7	86	2	3	1	6	2·33	3·49	1·16	6·98
8	86	2	3	1	6	2·33	3·49	1·16	6·98
9	86	2	3	1	6	2·33	3·49	1·16	6·98
10	86	2	3	1	6	2·33	3·49	1·16	6·98
11	86	2	3	1	6	2·33	3·49	1·16	6·98
12	86	2	3	1	6	2·33	3·49	1·16	6·98
13	86	2	3	1	6	2·33	3·49	1·16	6·98
14	86	2	3	1	6	2·33	3·49	1·16	6·98
15	86	2	3	1	6	2·33	3·49	1·16	6·98
16	86	2	3	1	6	2·33	3·49	1·16	6·98
17	86	2	3	1	6	2·33	3·49	1·16	6·98
18	86	2	3	1	6	2·33	3·49	1·16	6·98
19	86	2	3	1	6	2·33	3·49	1·16	6·98
20	86	2	3	1	6	2·33	3·49	1·16	6·98
21	86	2	3	1	6	2·33	3·49	1·16	6·98
22	86	2	3	1	6	2·33	3·49	1·16	6·98
23	86	2	3	1	6	2·33	3·49	1·16	6·98
24	86	2	3	1	6	2·33	3·49	1·16	6·98
Total	2,064	45	113	24	182	2·18	5·47	1·16	8·81

Factory L.1.

Table 11.—*Ages 23–27 (1st Jan., 1911—4th Aug., 1914).*

Length of time, in months.	Number employed.	Numbers Left.				Percentages.			
		Bad health.	Other sufficient reason.	No reason, or insufficient reason.	Total.	Bad health.	Other sufficient reason.	No reason, or insufficient reason.	Total
0	61	1	2	3	6	1·639	3·279	4·918	9·836
1	52	0	1	3	4	—	1·887	5·660	7·547
2	46	1	3	4	8	2·174	6·522	8·696	17·391
3	38	0	2	1	3	—	5·263	2·632	7·895
4	33	0	3	0	3	—	9·091	—	9·091
5	29	0	3	1	4	—	10·345	3·448	13·793
6	21	0	3	0	3	—	14·286	—	14·286
7	17	0	1	0	1	—	5·882	—	5·882
8	16	0	1	0	1	—	6·250	—	6·250
9	15	—	—	—	—	—	—	—	—
10	15	—	—	—	—	—	—	—	—
11	15	0	2	0	2	—	13·333	—	13·333
12	13	1	1	0	2	7·692	7·692	—	15·385
13	11	0	1	1	2	—	9·091	9·091	18·182
14	9	—	—	—	—	—	—	—	—
15	9	—	—	—	—	—	—	—	—
16	9	0	1	0	1	—	11·111	—	11·111
17	8	0	0	1	1	—	—	12·500	12·500
18	7	0	1	0	1	—	14·286	—	14·286
19	6	—	—	—	—	—	—	—	—
20	6	0	1	0	1	—	16·667	—	16·667
21	5	—	—	—	—	—	—	—	—
22	5	—	—	—	—	—	—	—	—
23	5	—	—	—	—	—	—	—	—
24	5	—	—	—	—	—	—	—	—
Totals	457	3	26	14	43	·656	5·689	3·063	9·409

Factory L.1

Table 12.—*Ages 13–17 (4th Aug., 1914—1st Dec., 1916).*

Length of time, in months.	Number employed.	Numbers Left.				Percentages.			
		Bad health.	Other sufficient reason.	No reason, or insufficient reason.	Total.	Bad health.	Other sufficient reason.	No reason, or insufficient reason.	Total
0	1,772	11	19	[illegible]	124	0·65	1·097	5·370	7·102
1	1,695	1	13	67	81	0·06	0·86	4·309	5·229
2	1,486	4	11	47	64	0·29	0·80	3·275	4·369
3	1,356	2	10	44	56	0·19	0·94	3·544	4·677
4	1,196	2	11	37	50	0·18	0·10	3·091	1·427
5	1,054	7	9	20	36	0·66	0·85	1·845	3·421
6	970	1	4	25	30	0·10	0·40	2·577	3·093
7	881	0	5	11	16	[illegible]	0·56	1·249	1·816
8	830	1	5	17	15	0·11	0·41	1·448	1·809
9	774	0	1	14	21	0·10	0·17	1·809	2·427
10	721	0	0	5	5	[illegible]	0·00	0·693	0·693
11	672	0	1	4	8	[illegible]	0·05	0·595	1·190
12	615	0	1	2	3	[illegible]	1·07	0·31	0·00
13	568	1	3	6	10	1·70	0·58	1·056	1·760
14	487	0	1	8	9	[illegible]	0·21	1·643	1·848
15	425	0	1	4	5	[illegible]	0·24	0·941	1·176
16	350	0	2	4	6	[illegible]	0·57	1·143	1·714
17	319	1	2	1	4	0·31	0·63	0·31	1·254
18	266	1	0	2	3	0·37	[illegible]	0·75	1·125
19	241	0	0	3	3	[illegible]	[illegible]	1·245	1·245
20	207	1	0	1	2	0·483	[illegible]	0·483	0·966
21	172	0	2	4	6	[illegible]	1·163	2·326	3·488
22	129	1	0	0	1	0·78	[illegible]	[illegible]	0·78
23	103	0	1	1	2	[illegible]	0·97	0·97	1·940
24	82	1	0	0	1	1·220	[illegible]	[illegible]	1·220
Totals	17,128	50	106	418	574	0·29	0·62	2·440	3·35

FACTORY L 1

TABLE 13.—*Ages 18–22 (All) Aug.* 1914—*1st Dec.* 1916[1]

Length of Time in months	Number of Cases	Notified Cases				Percentages			
		Total	Other Cases	Non-Pulmonary Cases	Deaths	Total	Other Cases	Non-Pulmonary Cases	Deaths
1	273	1	15	119	141	48	1·67	8·33	79
2	1,158	4	14	40	70	451	1·158	5·885	3·5
3	1,455	4	11	5	55	455	1·455	1·818	1·1·3
4	1,364	1	11	14	18	455	1·364	5·555	4·47
5	1,364	1	5	11	37	455	1·364	2·703	2·810
6	1,364			4	26		1·364	1·538	1·5·3
7	1,364	1		11	1	455	1·364	1·111	1·01
8	1,364			1	12	455	1·364	1·111	1·01
9	1,364				14	455	1·364	1·111	1·01
10	1,364	1	1	1	11	455	1·364	1·111	1·01
11	1,364	1	2	1	1	455	1·364	1·111	1·01
12	1,364	1	2	1	10	455	1·364	1·111	1·01
13	1,364		1	1	1	455	1·364	1·111	1·01
14	1,364			1	1	455	1·364	1·111	1·01
15	1,364			1	1	455	1·364	1·111	1·01
16	1,364			1	1	455	1·364	1·111	1·01
17	1,364			1	1	455	1·364	1·111	1·01
18	1,364			1	1	455	1·364	1·111	1·01
19	1,364			1	1	455	1·364	1·111	1·01
20	1,364			1	1	455	1·364	1·111	1·01
21	1,364			1	1	455	1·364	1·111	1·01
22	1,364			1	1	455	1·364	1·111	1·01
23	1,364			1	1	455	1·364	1·111	1·01
24	1,364			1	1	455	1·364	1·111	1·01
Totals	31,389	8	62	251	329	455	1·364	1·111	1·01

FACTORY L 1

TABLE 14.—*Ages 23–27 (All) Aug.* 1914—*1st Dec.* 1916[1]

Length of Time in months	Number of Cases	Notified Cases				Percentages			
		Total	Other Cases	Non-Pulmonary Cases	Deaths	Total	Other Cases	Non-Pulmonary Cases	Deaths
1	1,364	1		10	11	455	1·364	1·111	1·01
2	1,364			11	11	455	1·364	1·111	1·01
3	1,364			11	11	455	1·364	1·111	1·01
4	1,364	1		11	11	455	1·364	1·111	1·01
5	1,364	1	1	11	11	455	1·364	1·111	1·01
6	1,364	1	1	1	1	455	1·364	1·111	1·01
7	1,364			1	1	455	1·364	1·111	1·01
8	1,364			1	1	455	1·364	1·111	1·01
9	1,364			1	1	455	1·364	1·111	1·01
10	1,364			1	1	455	1·364	1·111	1·01
11	1,364			1	1	455	1·364	1·111	1·01
12	1,364			1	1	455	1·364	1·111	1·01
13	1,364			1	1	455	1·364	1·111	1·01
14	1,364			1	1	455	1·364	1·111	1·01
15	1,364			1	1	455	1·364	1·111	1·01
16	1,364			1	1	455	1·364	1·111	1·01
17	1,364			1	1	455	1·364	1·111	1·01
18	1,364			1	1	455	1·364	1·111	1·01
19	1,364			1	1	455	1·364	1·111	1·01
20	1,364			1	1	455	1·364	1·111	1·01
21	1,364			1	1	455	1·364	1·111	1·01
22	1,364			1	1	455	1·364	1·111	1·01
23	1,364			1	1	455	1·364	1·111	1·01
24	1,364			1	1	455	1·364	1·111	1·01
Totals	31,389	21	92	330	444	455	1·364	1·111	1·01

Factory L.1.

Table 15. *Ages 28 and over (4th Aug., 1914–1st Dec., 1916)*

Length of time, in months.	Number employed.	Numbers Left.				Percentages.			
		Bad health.	Other sufficient reason.	No reason, or insufficient reason.	Total.	Bad health.	Other sufficient reason.	No reason, or insufficient reason.	Total.
0	694	7	18	37	62	1·009	2·594	5·331	8·934
1	615	2	6	15	23	·325	·976	2·439	3·740
2	585	3	11	17	31	·513	1·880	2·906	5·299
3	530	0	6	9	15	—	1·132	1·698	2·830
4	472	3	4	8	15	·636	·847	1·695	3·178
5	423	2	11	8	21	·473	2·600	1·891	4·964
6	380	4	3	8	15	1·053	·789	2·105	3·947
7	344	0	0	6	6	—	—	1·747	1·747
8	304	1	0	3	4	·329	—	·987	1·315
9	262	1	—	1	5	·382	1·145	·382	1·908
10	222	0	—	3	3	—	—	1·351	1·351
11	184	1	2	2	5	·543	1·087	1·087	2·717
12	139	—	—	—	—	—	—	—	—
13	121	0	1	0	1	—	·826	—	·826
14	100	—	—	—	—	—	—	—	—
15	86	0	1	2	3	—	1·163	2·326	3·488
16	66	0	0	1	1	—	—	1·515	1·515
17	57	—	—	—	—	—	—	—	—
18	52	0	1	1	2	—	1·923	1·923	3·846
19	44	—	—	—	—	—	—	—	—
20	38	0	0	1	1	—	—	2·632	2·632
21	31	—	—	—	—	—	—	—	—
22	29	—	—	—	—	—	—	—	—
23	25	—	—	—	—	—	—	—	—
24	24	—	—	—	—	—	—	—	—
Total	5,829	24	85	143	252	412	1·459	2·453	3·656

Factory L.2.

Table 16.—*Ages 13–17 (1st Jan., 1911—4th Aug., 1914)*

Length of time, in months.	Number employed.	Numbers Left.				Percentages.			
		Bad health.	Other sufficient reason.	No reason, or insufficient reason.	Total.	Bad health.	Other sufficient reason.	No reason, or insufficient reason.	Total.
0	149	1	14	11	26	—	9·396	7·383	16·779
1	143	0	5	6	11	—	4·202	7·563	11·765
2	146	1	5	3	9	1·712	2·914	3·884	8·718
3	95	1	1	2	4	1·053	1·053	5·476	7·527
4	85	0	1	1	2	—	1·164	3·326	2·488
5	82	0	0	1	1	—	—	1·220	1·220
6	78	1	1	0	2	1·282	1·282	—	2·564
7	76	0	1	4	5	—	1·316	5·263	6·579
8	71	0	1	2	3	—	1·408	2·817	4·225
9	65	—	—	—	—	—	—	—	—
10	66	0	0	1	1	—	—	1·515	1·515
11	64	—	—	—	—	—	—	—	—
12	63	0	1	3	4	—	1·587	4·762	6·349
13	59	1	1	2	4	1·695	1·695	3·390	6·780
14	52	—	—	—	—	—	—	—	—
15	52	0	0	1	1	—	—	1·923	1·923
16	51	—	—	—	—	—	—	—	—
17	51	0	1	1	2	—	1·961	1·961	3·922
18	45	—	—	—	—	—	—	—	—
19	45	0	0	1	1	—	—	2·222	2·222
20	43	—	—	—	—	—	—	—	—
21	42	0	1	0	1	—	2·381	—	2·381
22	40	0	1	1	2	—	2·500	2·500	5·000
23	38	0	1	0	1	—	2·632	—	2·632
24	36	0	4	0	4	—	11·111	—	11·111
Total	1,732	5	47	48	100	·289	2·713	2·871	5·773

Factory L.2.

Table 17.—*Ages* 18–22 (*1st Jan.*, 1911—*4th Aug.*, 1914).

Length of time employed	Number employed	Number Left				Percentages			
		Bad health	Other sufficient reason	No reason, or insufficient reason	Total.	Bad health	Other sufficient reason	No reason, or insufficient reason	Total.
0	[illegible]	1	8	11	20	336	2·685	3·691	6·771
1	[illegible]	2	10	9	21	·763	3·817	3·436	8·015
2	[illegible]	0	4	6	10	—	1·878	2·817	4·695
3	[illegible]	1	7	8	16	493	3·448	3·941	7·882
4	187	—	—	2	4	—	1·070	1·070	2·139
5	184	1	—	—	5	·592	1·105	1·105	2·702
6	169	—	—	1	1	—	—	·592	·592
7	166	1	4	1	6	·602	2·410	·602	3·614
8	149	0	2	0	2	—	1·258	—	1·258
9	147	0	—	—	7	—	3·185	1·274	4·459
10	151	—	1	0	1	—	·667	—	·667
11	145	0	4	3	7	—	2·685	2·013	4·698
12	141	—	—	—	7	—	4·418	3·546	4·965
13	144	—	6	2	8	—	4·511	1·404	6·915
14	141	—	—	1	4	—	2·160	·820	2·279
15	134	1	—	1	7	·887	4·386	·877	6·140
16	103	—	—	1	4	—	2·913	·971	3·883
17	[illegible]	—	—	—	—	—	—	—	—
18	97	—	4	0	4	—	4·124	—	4·124
19	91	0	—	2	5	—	3·297	2·198	5·495
20	84	—	—	—	—	—	—	—	—
21	83	1	—	0	1	1·205	2·410	—	2·614
22	77	1	—	1	4	1·299	2·597	1·298	5·195
23	[illegible]	0	2	2	4	—	2·740	2·740	5·479
24	69	0	0	1	1	—	—	1·493	1·493
Total	[illegible]	9	81	61	151	·372	3·304	1·744	4·220

Factory L.2.

Table 18.—*Ages* 13–17 (*4th Aug.*, 1914—*1st Dec.* 1916).

Length of time employed	Number employed	Number Left				Percentages			
		Bad health	Other sufficient reason	No reason, or insufficient reason	Total.	Bad health	Other sufficient reason	No reason, or insufficient reason	Total.
0	711	1	1	12	16	141	1·477	5·674	7·585
1	182	1	5	4	10	549	7·747	2·198	5·495
2	167	6	2	11	15	—	1·197	7·784	8·981
3	142	1	2	4	7	704	1·408	2·817	4·930
4	108	0	2	3	5	—	1·904	2·944	3·809
5	114	1	0	6	7	877	—	5·177	6·054
6	97	0	2	1	3	—	2·062	1·031	3·092
7	90	0	1	0	1	—	1·111	—	1·111
8	83	—	—	—	—	—	—	—	—
9	74	0	0	3	3	—	—	4·054	4·054
10	67	0	2	0	2	—	2·985	—	2·985
11	61	—	—	—	—	—	—	—	—
12	58	—	1	1	2	—	1·724	1·724	3·448
13	56	0	0	1	1	—	—	1·786	1·786
14	50	0	0	1	1	—	—	2·000	2·000
15	48	0	1	0	1	—	2·083	—	2·083
16	43	0	1	0	1	—	2·326	—	2·326
17	41	—	—	—	—	—	—	—	—
18	39	—	—	—	—	—	—	—	—
19	35	—	—	—	—	—	—	—	—
20	28	—	—	—	—	—	—	—	—
21	23	—	—	—	—	—	—	—	—
22	16	—	—	—	—	—	—	—	—
23	15	0	0	1	1	—	—	6·667	6·667
24	13	—	—	—	—	—	—	—	—
Total	1 883	4	22	50	76	·212	1·168	2·655	4·036

Factory L 2

Table 19.—*Ages* 18–22 (*4th Aug.*, 1914—*1st Dec.*, 1916).

Length of time, in months.	Number employed.	Numbers Left.				Percentages.			
		Bad health.	Other sufficient reason.	No reason, or insufficient reason.	Total.	Bad health.	Other sufficient reason.	No reason, or insufficient reason.	Total.
0	894	5	15	67	87	·622	1·866	8·333	10·821
1	668	7	16	33	56	1·047	2·395	4·940	8·383
2	688	5	4	25	34	·850	·680	4·252	5·782
3	512	2	8	21	31	·391	1·563	4·102	6·054
4	450	1	3	18	22	·222	·667	4·000	4·889
5	385	3	9	12	24	·779	2·338	3·377	6·234
6	338	0	4	5	9	—	1·183	1·479	2·663
7	313	1	2	6	9	·319	·639	1·917	2·875
8	292	1	2	8	11	·342	·685	2·740	3·767
9	259	1	0	3	4	·386	—	1·158	1·544
10	249	0	0	4	4	—	—	1·606	1·606
11	225	3	0	6	9	1·333	—	2·667	4·000
12	191	1	1	5	7	·524	·524	2·619	3·667
13	172	1	0	2	3	·581	—	1·163	1·744
14	159	0	2	0	2	—	1·259	—	1·259
15	149	1	0	1	2	·671	—	·671	1·342
16	131	0	3	3	6	—	2·290	2·290	4·580
17	116	—	—	—	—	—	—	—	—
18	110	0	3	3	6	—	2·727	2·727	5·454
19	92	0	1	0	1	—	1·087	—	1·087
20	71	0	0	1	1	—	—	1·408	1·408
21	48	0	1	0	1	—	2·083	—	2·083
22	39	0	0	3	3	—	—	7·692	7·692
23	36	0	1	1	2	—	2·778	2·778	5·556
24	30	0	1	0	1	—	3·333	—	3·333
Totals	6,427	52	76	227	335	·808	1·183	3·532	5·215

Factory L 2

Table 20.—*Ages* 23–27 (*4th Aug.*, 1914—*1st Dec.*, 1916).

Length of time, in months.	Number employed.	Numbers Left.				Percentages.			
		Bad health.	Other sufficient reason.	No reason, or insufficient reason.	Total.	Bad health.	Other sufficient reason.	No reason, or insufficient reason.	Total.
0	515	2	19	46	67	·388	3·689	8·932	13·010
1	404	5	9	20	34	·248	2·228	4·950	8·416
2	355	1	13	21	35	·282	3·662	5·915	9·859
3	275	0	3	16	19	—	1·090	5·818	6·909
4	228	1	1	10	12	·439	·439	4·386	5·263
5	186	3	1	2	6	1·613	·538	1·075	3·226
6	165	0	1	5	6	—	·606	3·030	3·636
7	146	1	3	1	5	·685	2·055	·685	3·425
8	123	0	1	1	2	—	·813	·813	1·626
9	108	1	3	0	4	·926	2·778	—	3·704
10	97	1	0	1	2	1·031	—	1·031	2·062
11	81	2	0	4	6	2·469	—	4·938	7·407
12	66	0	0	1	1	—	—	1·515	1·515
13	58	—	—	—	—	—	—	—	—
14	51	—	—	—	—	—	—	—	—
15	47	—	—	—	—	—	—	—	—
16	44	0	0	1	1	—	—	2·273	2·273
17	39	—	—	—	—	—	—	—	—
18	34	1	0	0	1	2·941	—	—	2·941
19	30	—	—	—	—	—	—	—	—
20	22	—	—	—	—	—	—	—	—
21	16	—	—	—	—	—	—	—	—
22	10	—	—	—	—	—	—	—	—
23	10	—	—	—	—	—	—	—	—
24	8	—	—	—	—	—	—	—	—
Totals	3,118	18	54	129	201	·577	1·732	4·137	6·446

Factory L.2

Table 21. *Ages 28 and over (4th Aug., 1914—1st Dec., 1916).*

Length of time in months	Numbers completed	Numbers Left: Bad health	Other suffi-cient reason	No reason or insuffi-cient reason	Total	Percentages: Bad health	Other suffi-cient reason	No reason or insuffi-cient reason	Total.
0	1,[illegible]	7	11	73	91	5·85	9·19	6·[illegible]	7·60
1	1,[illegible]	11	13	40	64	1·089	1·287	3·960	6·427
2	[illegible]	9	7	32	48	1·008	7·84	4·703	6·495
3	[illegible]	1	2	24	27	1·36	1·635	1·250	5·041
4	[illegible]	4	4	13	21	7·07	7·07	2·2·47	4·249
5	147	0	6	9	15	—	1·332	1·[illegible]13	2·374
6	1,[illegible]85	1	2	7	10	2·58	5·17	1·808	2·884
7	3[illegible]	1	3	5	10	2·87	1·146	1·[illegible]3	2·80[illegible]
8	1,[illegible]85	2	2	2	6	4·07	6·07	4·07	2·[illegible]1
9	[illegible]	1	1	4	6	4·31	4·31	1·724	2·58
10	1[illegible]	1	1	0	2	4·71	4·71	—	1·[illegible]
11	[illegible]	0	0	1	1	—	—	4·71	4·71
12	1,[illegible]41	1	0	1	2	7·09	—	7·09	1·428
13	[illegible]	0	1	0	1	—	9·09	—	[illegible]
14	89	0	0	1	1	—	—	1·124	1·124
15	86	1	0	0	1	1·163	—	—	1·163
16	54								
17	45	—	—	—	—	—	—	—	—
18	39	—	—	—	—	—	—	—	—
19	34	1	1	0	2	2·85·2	2·85·2	—	5·[illegible]4
20	33	—	—	—	—	—	—	—	—
21	24	—	—	—	—	—	—	—	—
22	20	0	0	1	1	—	—	[illegible]	[illegible]
23	15	—	—	—	—	—	—	—	—
24	13	—	—	—	—	—	—	—	—
Totals	7,272	41	6[illegible]	223	329	[illegible]64	891	[illegible]067	4·524

Factories L.1 and L.2

Table 22

Previous Occupations of Employees (Percentages).

Occupation	Number in sample	Manufacturing Wage earners	Domestic Out of Service	Shop Assistants	Miners	Persons never at work before joining Army	Gain caused
Peace time. Ages 15–17 (1,[illegible]0[illegible])	[illegible]	5·43	8·85	6·41	1·63	54·21	2·44
War time. Ages 15–17 (1,[illegible]41)	[illegible]·61	9·47	8·95	3·78	1·71	51·58	[illegible]·21
Peace time. Ages 18–20 (3,[illegible]70)	[illegible]·[illegible]	16·05	18·87	5·26	3·85	24·41	1·61
War time. Ages 18–20 (2,[illegible])	2[illegible]·[illegible]	13·47	21·02	5·03	1·31	30·60	1·31
Peace time. Ages 21–27 (4,[illegible]10)	29·21	30·09	22·73	5·45	·91	10·39	1·04
War time. Ages 21–27 (1,143)	17·39	22·75	21·61	3·24	2·36	18·17	13·[illegible]
War time. Ages 28– (1,905)	12·86	19·11	12·18	1·57	2·89	12·65	8·74

Table 23.

Numbers remaining at Work out of 1,000 Entrants in accordance with Various Rates of Loss.

Remaining after months	Orphan Factory (War times.	L.2 Factory (War times.	L.1 Factory (War times.	L.1 Factory (Peace times.	L.1 Factory (Peace times, ages 18–22).	L.1 Factory (War times, ages 18–22).	L.1 Factory (War times, ages 14–17.	L.1 Factory (War times, ages 23–27.	L. Factory (War times, ages 28–
0	1,000	1,000	1,000	1,000	[illegible]	1,000	1,000	1,000	1,000
1	892	904	917	921	928	902	[illegible]	[illegible]	[illegible]
2	832	839	868	855	848	853	881	[illegible]	877
3	778	779	826	795	800	813	841	843	8[illegible]
4	733	735	791	749	754	778	799	777	807
5	691	703	757	703	710	749	764	729	781
6	657	671	730	658	668	727	743	698	742

Table 24

Tests of Consistency. (See Appendix.)

Statistics compared	Groupings used.	Q.	χ^2	P
Ages 14–17 and 18–22 War times. L.1 [illegible] of Survivors	0 and 1, 2 and 3, 4 and 5, 6 and over.	4·98665	1·[illegible]	·2428
Ages 18–22 [illegible] and War times [illegible]	0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 13, 14 and over.	89·7939	97·[illegible]18	V[illegible]
Ages [illegible]0, 28– L.1 and L.2 War times	0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 13, 14 and over.	15·4186	15·0892	·1788
Ages [illegible] 13–17 and 18–22 L.1 War times. All [illegible]	0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 13, 14 and over.	16·2453	16·2 [illegible]	[illegible]·2[illegible]

FACTORY L.7.

TABLE 25.—Ages under 22 (1st June, 1916—1st July, 1917).

Number of Weeks under Notice	Number Employed	Number Employed				Percentages			
		Book-keeping Staff	Other Female Staff	Male Staff	Total	Book-keeping Staff	Other Female Staff	Male Staff	Total.
1	[illegible]	1	3	1	5	[illegible]	1·071	1·204	2·551
1	[illegible]	1	3	—	4	751	1·054	—	1·805
2	163	1	—	—	1	606	—	—	606
3	133	—	—	—	—	—	—	—	—
4	167	—	—	—	—	—	—	—	—
5	[illegible]	1	3	—	4	1·003	2·976	—	4·054
6	[illegible]	—	—	1	1	—	—	1·667	1·667
7	98	—	—	—	—	—	—	—	—
8	[illegible]	—	—	—	—	—	—	—	—
9	[illegible]	—	—	—	—	—	—	—	—
10	[illegible]	—	—	—	—	—	—	—	—
11	[illegible]	—	—	—	—	—	—	—	—
12	[illegible]	—	—	—	—	—	—	—	—
13	[illegible]	—	—	—	—	—	—	—	—
14	[illegible]	—	—	—	—	—	—	—	—
15	[illegible]	—	—	—	—	—	—	—	—
Over 15	[illegible]	—	—	—	—	—	—	—	—
Total	1,331	3	10	—	13	[illegible]	[illegible]	[illegible]	[illegible]

FACTORY L.7

TABLE 26.—Ages 22-27 (1st June, 1916—1st July, 1917).

Number of Weeks under Notice	Number Employed	Number Employed				Percentages			
		Book-keeping Staff	Other Female Staff	Male Staff	Total	Book-keeping Staff	Other Female Staff	Male Staff	Total.
1	[illegible]	—	—	—	—	[illegible]	[illegible]	[illegible]	[illegible]
1	[illegible]	—	—	1	1	[illegible]	[illegible]	[illegible]	[illegible]
2	[illegible]	—	—	—	—	[illegible]	—	—	[illegible]
3	[illegible]	1	—	—	1	[illegible]	—	—	[illegible]
4	[illegible]	—	1	—	1	—	[illegible]	—	[illegible]
5	[illegible]	—	—	—	—	—	—	—	—
6	[illegible]	—	—	—	—	—	—	—	—
7	[illegible]	—	—	—	—	—	—	—	—
8	[illegible]	—	—	—	—	—	—	—	—
9	[illegible]	—	—	—	—	—	—	—	—
10	[illegible]	—	—	—	—	—	—	—	—
11	[illegible]	—	—	—	—	—	—	—	—
12	[illegible]	—	—	—	—	—	—	—	—
13	[illegible]	—	—	—	—	—	—	—	—
Over 13	[illegible]	—	—	—	—	—	—	—	—
Total	[illegible]	1	1	—	2	[illegible]	[illegible]	—	[illegible]

Factory L.7.

Table 27.—*Ages over 28 (1st Jan., 1916 - 1st Feb., 1917).*

Length of service.	Number employed.	Numbers Left.				Percentages.			
		Bad health.	Other sufficient reason.	No reason, or insufficient reason.	Total.	Bad health.	Other sufficient reason.	No reason, or insufficient reason.	Total.
0	306	—	9	13	22	-	3·000	4·333	7·333
1	269	3	5	2	10	1·115	1·859	·743	3·717
2	124	—	1	1	2	-	·806	·806	1·613
3	98	-	2	-	2	-	2·041	—	2·041
4	78	-	-	—	—	—	—	—	—
5	61	2	1	—	3	3·279	1·639	—	4·918
6	45	—	—	—	—	—	—	—	—
7	26	-	—	—	—	—	—	—	—
8	2	-	—	—	—	—	—	—	—
9	1	—	-	—	—	—	—	—	—
10	1	-	—	—	—	—	—	—	—
11	1	—	—	-	—	—	—	-	-
12	0	—	—	—	—	—	-	—	-
Over 12	0	—	-	-	—	—	-	—	-
Total...	1,096	5	18	16	39	·457	1·789	1·590	3·877

Factory L.7.

Table 28.—*All ages (1st Jan., 1916 - 1st Feb., 1917).*

Length of service.	Number employed.	Number Left.				Percentages.			
		Bad health.	Other sufficient reason.	No reason, or insufficient reason.	Total.	Bad health.	Other sufficient reason.	No reason, or insufficient reason.	Total.
0	901	3	18	24	45	·333	1·998	2·664	4·994
1	818	4	12	3	19	·489	1·467	·367	2·324
2	377	2	1	1	4	·531	·265	·265	1·061
3	312	1	2	—	3	·321	·641	—	·962
4	247	—	1	—	1	—	·405	—	·405
5	178	3	3	—	6	1·685	1·685	—	3·371
6	143	—	—	1	1	—	—	·699	·699
7	90	—	—	—	—	—	—	—	—
8	5	—	—	—	—	—	—	—	—
9	3	—	—	—	—	—	—	—	—
10	3	—	—	—	—	—	—	—	—
11	2	-	—	—	—	—	—	—	—
12	1	—	—	—	-	—	—	—	—
Over 12	0	—	—	—	—	—	—	—	—
Total	2,089	13	37	29	79	·422	1·201	·942	2·565

TABLE 29.—*Observed Losses of L 7 compared with those expected from the Experience of Factory L 1*

Under 22			Ages 23–27			Over 28			All Ages		
	L 7	L 1		L 7	L 1		L 7	L 1		L 7	L 1
0	11	43·18	0	12	26·78	0	22	22·81	[illegible]	45	92·77
1	5	30·03	1	4	15·15	1	10	11·05	2	19	56·23
2	1	9·51	2	1	8·08	2	2	8·05	3	4	26·27
3		8·12	3	1	5·18	3	2	4·04	5	3	18·34
4		5·23	4	1	4·20	4		2·80	4	1	11·23
5	3	4·61	5	—	1·00	5	1	1·05	8	6	8·01
6	1	1·60	6	—	·58	6	—	1·16	6	1	4·13
7	—	1·04	7	—	·00	7	—	·73	7	—	3·77
8		·04	8		·00	8		·54	8		1·1
9	—	·02	9	—	·04	9	—	·05	9	—	·11
10		·02	10	—	·02	10			10	—	·04
11		·04	11			11			11		·04
12	—	·04	12	—	—	12	—	—	12		·04
Over 12		—	Over 12			Over 12			Over 12		
Total	21	104·71	Total	19	65·37	[illegible]	39	80·76	[illegible]	79	250·84

TABLE 30.—*Under 22*

	Household Work	Sewing	Fancy Work	Reading	Sewing Machine	Machine Operation	Fancy Machine	Total Sewing Machine
L 7	14·44	16·45	11·42	5·93	19·89	1·37	9·48	42·8
L 2	28·91	23·34	37·47	1·40	4·71	1·61	7·48	86·1
Ages 23–27								
L 7	19·16	19·73	5·61	7·94	15·35	2·80	51·31	41·0
L 2	18·56	21·97	35·13	76	4·17	1·33	17·80	92·8
Over 28								
L 7	37·12	27·30	0·76	1·21	5·62	1·68	14·31	70·6
L 2	13·60	11·60	29·35	1·92	1·53	1·60	41·91	1·08

FACTORY L.4. TABLE 31.—*Ages* 13–17 (*1st Jan.*, 1916—*1st Dec.*, 1916).

Length of Time, in Months.	Number Employed	Numbers Left					Percentages.				
		Bad Health	Medical Rejection	Other Sufficient Reason.	No Reason or Insufficient Reason	Total.	Bad Health	Medical Rejection	Other Sufficient Reason.	No Reason or Insufficient Reason	Total.
0	369	3	—	3	28	34	·813	—	·813	7·588	9·214
1	306	1	1	3	5	10	·327	·327	·980	1·634	3·268
2	268	1	2	4	5	12	·373	·746	1·493	1·866	4·478
3	179	1	3	3	—	7	·559	1·676	1·676	—	3·911
4	104	—	—	—	2	2	—	—	—	1·923	1·923
5	70	—	—	1	2	3	—	—	1·429	2·857	4·286
6	42	—	—	—	1	1	—	—	—	2·381	2·381
7	23	2	—	1	—	3	8·696	—	4·348	—	13·043
8	11	—	—	—	—	—	—	—	—	—	—
9	7	—	—	—	—	—	—	—	—	—	—
10	2	—	—	—	—	—	—	—	—	—	—
Totals	1,381	8	6	15	43	72	·579	·434	1·086	3·114	5·214

FACTORY L.4. TABLE 32.—*Ages* 18–22 (*1st Jan.*, 1916—*1st Dec.*, 1916).

0	960	18	8	11	27	64	1·875	·833	1·146	2·813	6·667
1	821	14	3	8	17	42	1·705	·368	·974	2·071	5·116
2	725	11	2	5	18	36	1·517	·276	·690	2·483	4·966
3	519	3	7	9	10	29	·578	1·349	1·734	1·927	5·588
4	318	2	2	2	6	12	·629	·629	·629	1·887	3·774
5	221	5	1	4	7	17	2·262	·452	1·810	3·167	7·692
6	151	3	—	2	2	7	1·987	—	1·325	1·325	4·636
7	109	1	1	1	—	3	·917	·917	·917	—	2·752
8	80	—	1	—	2	3	—	1·250	—	2·500	3·750
9	24	1	—	1	1	3	4·167	—	4·167	4·167	12·500
10	9	1	—	—	1	2	11·111	—	—	11·111	22·222
Totals ..	3,937	59	25	43	91	218	1·499	·635	1·092	2·311	5·537

FACTORY L 4. TABLE 33.—*Ages 23-27 (1st Jan., 1916 - 1st Dec., 1916)*

Length of Term in Months	Number Employed	Number Left					Percentage				
		Died	Invalided	Other Causes	No Reason or Information	Total	Died	Invalided	Other Causes	No Reason or Information	Total
0	810	12	2	14	15	41	2 469	617	2 057	2 469	7 980
1	486	6	—	9	17	29	1 853	—	1 853	3 058	6 744
2	375	4	2	8	10	21	1 067	533	2 133	2 667	5 600
3	275	3	3	2	4	12	1 091	1 091	727	1 455	4 364
4	178	—	—	1	1	2	—	—	562	562	1 124
5	129	1	—	1	—	2	775	—	775	—	1 550
6	94	1	—	—	1	2	1 064	—	—	1 064	2 128
7	73	1	—	1	1	3	1 370	—	1 370	1 370	4 110
8	53	1	—	1	1	3	1 887	—	1 887	1 887	5 660
9	13	—	—	—	1	1	—	—	—	7 692	7 692
10	6	—	—	—	—	—	—	—	—	—	—
Totals	2 145	26	7	34	49	116	1 212	326	1 584	2 284	5 408

FACTORY L 4. TABLE 34.—*Ages 28 (1st Jan., 1916 - 1st Dec., 1916)*

0	576	11	3	4	16	34	1 910	521	695	2 778	5 904
1	419	8	1	10	11	30	1 909	454	2 386	2 626	7 375
2	366	5	3	9	8	25	1 366	821	2 459	1 366	6 012
3	308	5	2	4	6	17	1 623	649	1 298	1 948	5 518
4	245	8	—	3	4	15	3 265	—	1 224	2 041	6 530
5	183	—	—	2	3	5	—	—	1 093	1 639	2 732
6	116	2	—	1	—	3	1 724	—	862	—	2 586
7	81	1	—	—	—	1	1 235	—	—	—	1 235
8	52	—	—	—	1	1	—	—	—	1 818	1 818
9	25	—	—	—	—	—	—	—	—	—	—
10	11	—	—	1	—	1	—	—	9 091	—	9 091
11	1	1	—	—	—	1	100 000	—	—	—	100 000
Totals	2,617	38	9	36	50	133	1 452	344	1 376	1 911	5 082

FACTORY L.4. TABLE 35.—*All Ages* (1*st Jan.* 1916—1*st Dec.*, 1916)

Length of Time in Months	Number Employed	Numbers Left.					Percentages				
		Bad Health.	Medical Rejection.	Other Sufficient Reason.	No Reason or Insufficient Reason.	Total.	Bad Health.	Medical Rejection.	Other Sufficient Reason.	No Reason or Insufficient Reason	Total.
0	2,324	44	13	32	84	173	1·815	536	1·320	3·465	7·137
1	2,072	29	5	27	50	111	1·400	241	1·303	2·413	5·357
2	1,864	18	9	26	41	94	981	491	1·418	2·236	5·125
3	1,341	12	15	18	20	65	895	1·119	1·342	1·491	4·847
4	845	7	2	8	14	31	828	237	947	1·657	3·669
5	583	6	1	8	12	27	1·029	172	1·372	2·058	4·631
6	403	6	—	3	4	13	1·489	—	744	993	3·226
7	286	5	1	3	1	10	1·748	350	1·049	350	3·497
8	199	1	1	1	4	7	503	503	503	2·010	3·518
9	64	1	—	1	2	4	1·563	—	1·563	3·125	6·250
10	28	1	—	1	1	3	3·571	—	3·571	3·571	10·714
11	1	1	—	—	—	1	100·000	—	—	—	100·000
Totals ..	10,080	131	47	128	233	539	1·300	·466	1·270	2·312	5·347

FACTORY L.5 TABLE 36.—*Ages* 13–17 (1*st Jan.*, 1916—1*st Dec.*, 1916)

0	76	1	—	—	—	1	1·316	—	—	—	1·316
1	71	2	—	—	—	2	2·817	—	—	—	2·817
2	63	—	—	—	1	1	—	—	—	1·587	1·587
3	50	—	—	—	1	1	—	—	—	2·000	2·000
4	45	—	—	2	—	2	—	—	4·444	—	4·444
5	38	—	—	—	—	—	—	—	—	—	—
6	21	—	—	—	—	—	—	—	—	—	—
7	14	—	—	—	—	—	—	—	—	—	—
8	7	—	—	—	—	—	—	—	—	—	—
9	1	—	—	—	—	—	—	—	—	—	—
Totals ..	386	3	—	2	2	7	·815	—	·543	·543	1·902

FACTORY L 5 TABLE 37 — *Ages* 18-22 (*1st Jan.*, 1916–*1st Dec.*, 1916)

Length of Time in Months	Number Employed	Sickness Lost					Expenditure				
		Bad Health	Medical Inspection	Other Sufficient Reason	No Reason or Insufficient Reason	Total	Bad Health	Medical Inspection	Other Sufficient Reason	No Reason or Insufficient Reason	Total
0	1,496	7	10	6	5	28	468	668	401	334	1,872
1	1,263	6	13	6	9	34	478	1,629	478	713	2,692
2	980	2	5	1	11	19	208	831	104	1,146	1,979
3	684	4	9	2	4	19	602	1,458	401	602	2,861
4	505	3	1	2	6	12	594	792	396	1,188	2,970
5	344	1	2	1	3	7	200	400	200	808	2,096
6	171	2	—	1	1	4	1,653	—	826	826	3,306
7	76	—	—	2	—	2	—	—	2,632	—	2,632
8	47	—	—	—	1	1	—	—	—	2,128	2,128
9	29	—	1	—	2	3	—	3,448	—	6,897	10,345
Total	5,495	25	44	21	42	132	455	801	482	764	2,402

FACTORY L 5 TABLE 38 — *Ages* 23-27 (*1st Jan.*, 1916—*1st Dec.*, 1916)

0	586	2	—	3	3	8	338	—	677	338	1,384
1	522	2	2	2	6	12	383	383	383	1,149	2,299
2	427	3	2	1	4	10	703	468	234	937	2,342
3	314	1	2	—	2	5	318	637	—	637	1,592
4	270	2	2	3	4	11	741	741	1,111	1,481	4,074
5	196	1	2	1	6	10	510	1,020	510	3,061	5,102
6	98	—	—	—	—	—	—	—	—	—	—
7	68	—	1	—	1	2	—	1,471	—	1,471	2,941
8	6	—	—	—	1	1	—	—	—	3,333	3,333
9	17	—	—	—	1	1	—	—	—	5,882	5,882
Total	2,531	11	11	11	27	60	435	435	435	1,067	2,371

FACTORY L.5. TABLE 39.—*Ages* 28 (1*st Jan.*, 1916—1*st Dec.*, 1916).

Length of Time, in Months	Number Employed	Numbers Left					Percentages.				
		Bad Health	Medical Rejection	Other Sufficient Reason.	No Reason or Insufficient Reason.	Total.	Bad Health	Medical Rejection	Other Sufficient Reason.	No Reason or Insufficient Reason.	Total.
0	421	3	—	6	3	12	·713	—	1·425	·713	2·850
1	364	2	—	—	6	8	549	—	—	1·648	2·198
2	310	5	—	5	8	18	1·613	—	1·613	2·581	5·806
3	248	—	—	1	1	2	—	—	·403	·403	·806
4	214	—	1	—	2	3	—	·467	—	·935	1·402
5	179	1	3	3	3	10	·559	1·676	1·676	1·676	5·587
6	96	—	—	4	1	5	—	—	4·167	1·042	5·208
7	66	—	—	—	—	—	—	—	—	—	—
8	29	—	1	—	—	1	—	3·448	—	—	3·448
9	17	—	—	—	—	—	—	—	—	—	—
10	2	—	—	—	1	1	—	—	—	50·000	50·000
Totals ..	1,946	11	5	19	25	60	·565	·257	·976	1·285	3·083

FACTORY L.5. TABLE 40.—*All Ages* (1*st Jan.*, 1916—1*st Dec.*, 1916).

0	2,584	13	10	16	10	49	·503	·387	·619	·387	1·896
1	2,220	12	15	8	21	56	·541	·676	·360	·946	2·523
2	1,760	10	7	7	24	48	·568	·398	·398	1·364	2·727
3	1,276	5	11	3	8	27	·392	·862	·235	·627	2·116
4	1,034	5	7	7	12	31	·484	·677	·677	1·161	3·998
5	747	3	7	5	12	27	·402	·937	·669	1·606	3·614
6	333	2	—	5	2	9	·599	—	1·497	·599	2·695
7	224	—	1	2	1	4	—	·446	·893	·446	1·786
8	113	—	1	—	2	3	—	·885	—	1·770	2·655
9	64	—	1	—	3	4	—	1·563	—	4·688	6·250
10	2	—	—	—	1	1	—	—	—	50·000	50·000
Totals .	10,358	50	60	53	96	259	·483	·579	·512	·927	2·500

Factory H 3 Table 41.—*Ages 18-22*

(*1st March 1916 to 1st March 1917*)

Length of time, in months.	Number [illegible]	Number Lost				Percentages.			
		11 months	[illegible]	[illegible]	Total.	11 months	[illegible]	[illegible]	Total.
0	570	—	11	11	22	—	2·105	3·684	0·800
1	291	4	11	6	21	1·775	4·811	2·162	8·247
2	247	—	1	11	12	·544	1·747	4·053	7·505
3	181	—	1	6	7	1·105	6·243	4·912	9·302
4	143	—	1	1	2	1·849	·707	2·707	1·805
5	132	—	2	6	8	—	1·515	4·545	6·061
6	123	—	—	5	5	—	—	4·065	4·065
7	169	1	1	4	6	·943	·937	3·774	5·659
8	67	2	1	2	5	2·985	1·493	2·985	7·463
9	40	—	—	—	—	—	—	—	—
10	36	—	—	—	—	—	—	—	—
11	13	—	—	—	—	—	—	—	—
12	0	—	—	—	—	—	—	—	—
Totals	1,740	10	46	62	121	·743	2·650	3·565	6·218

Factory H 3 Table 42.—*Ages 23-27*

(*1st March 1916 to 1st March 1917*)

Length of [illegible] in months.	Number [illegible]	Number Lost				Percentages.			
		11 months	[illegible]	[illegible]	Total.	11 months	[illegible]	[illegible]	Total.
0	339	5	13	15	33	1·471	3·824	4·412	9·706
1	247	6	13	8	28	2·429	5·263	3·239	11·336
2	206	2	10	9	21	·971	4·854	4·369	10·194
3	160	3	6	13	22	1·875	3·750	7·812	13·438
4	125	—	4	7	11	—	3·200	5·185	8·148
5	123	3	1	5	9	2·439	·813	4·065	7·317
6	103	3	2	10	15	2·913	1·942	9·709	14·564
7	86	2	2	2	6	2·326	2·326	2·326	6·977
8	43	—	—	2	2	—	—	4·652	4·652
9	41	—	—	1	1	—	—	2·439	2·439
10	33	—	—	1	1	—	—	3·030	3·030
11	16	—	—	—	—	—	—	—	—
12	0	—	—	—	—	—	—	—	—
Totals	1,504	24	51	73	148	1·595	3·391	4·855	9·841

Factory H 3 Table 43.—*Over 28*

(*1st March 1916 to 1st March 1917*)

Length of [illegible] in months.	Number [illegible]	Number Lost				Percentages.			
		11 months	[illegible]	[illegible]	Total.	11 months	[illegible]	[illegible]	Total.
0	874	10	30	36	76	1·150	3·436	4·119	8·695
1	611	13	42	20	75	2·128	6·874	3·273	12·275
2	506	6	28	18	47	1·187	5·534	3·557	9·280
3	410	4	26	25	49	·976	6·341	6·098	11·951
4	320	4	10	15	29	1·250	3·125	4·688	9·063
5	286	1	6	14	21	·350	2·098	4·895	7·343
6	248	5	2	9	16	2·016	·806	3·629	6·452
7	203	—	3	7	10	—	1·478	3·448	4·926
8	140	—	—	6	6	—	—	4·286	4·286
9	99	—	1	1	2	—	1·010	1·010	2·020
10	91	—	—	3	3	—	—	3·297	3·297
11	47	—	—	2	2	—	—	4·255	4·255
12	0	—	—	—	—	—	—	—	—
Totals	3,795	43	147	156	336	1·133	3·610	4·111	8·854

Factory H.2. Table 44.—*Ages* 18–22.

(*1st July*, 1916—*1st March*, 1917.)

Length of time, in months.	Number employed.	Number Left.				Percentages.			
		Ill-health.	Other causes.	Insufficient reason.	Total.	Ill-health.	Other causes.	Insufficient reason.	Total.
0	216	2	6	9	17	·926	2·778	4·167	7·870
1	150	2	5	6	13	1·333	3·333	4·000	8·667
2	108	2	—	2	4	1·852	—	1·852	3·704
3	74	—	—	4	4	—	—	5·405	5·405
4	53	—	—	2	2	—	—	3·774	3·774
5	49	—	—	2	2	—	—	4·082	4·082
6	46	—	—	4	4	—	—	8·696	8·696
7	21	—	—	2	2	—	—	9·524	9·524
8	0	—	—	—	—	—	—	—	—
Totals	717	6	11	31	48	·837	1·534	4·324	6·695

Factory H.2. Table 45.—*Ages* 23–27.

(*1st July*, 1916—*1st March*, 1917.)

Length of time, in months.	Number employed.	Number Left.			Total.	Percentages.			
		Ill-health.	Other causes.	Insufficient reason.		Ill-health.	Other causes.	Insufficient reason.	Total.
0	192	6	11	18	35	3·125	5·729	9·375	18·229
1	115	—	1	2	3	—	·870	1·739	2·609
2	97	1	1	4	6	1·031	1·031	4·124	6·186
3	63	1	—	2	3	1·587	—	3·175	4·762
4	40	—	—	1	1	—	—	2·500	2·500
5	35	—	—	—	—	—	—	—	—
6	33	—	1	3	4	—	3·030	9·091	12·121
7	14	—	—	1	1	—	—	7·143	7·143
8	0	—	—	—	—	—	—	—	—
Totals	589	8	14	31	53	1·358	2·377	5·263	8·998

Factory H.2. Table 46.—*Over* 28.

(*1st July*, 1916—*1st March*, 1917.)

Length of time, in months.	Number employed.	Number Left.				Percentages.			
		Ill-health.	Other causes.	Insufficient reason.	Total.	Ill-health.	Other causes.	Insufficient reason.	Total.
0	464	21	33	31	85	4·526	7·112	6·681	18·319
1	332	5	9	21	35	1·506	2·711	6·325	10·542
2	268	2	6	16	24	·746	2·239	5·970	8·955
3	195	1	0	8	9	·513	—	4·103	4·615
4	152	2	3	5	10	1·316	1·974	3·289	6·579
5	137	—	1	4	5	—	·730	2·920	3·650
6	123	1	1	6	8	·813	·813	4·878	6·504
7	62	—	—	3	3	—	—	4·839	4·839
8	3	—	—	—	—	—	—	—	—
9	0	—	—	—	—	—	—	—	—
Totals	1,736	32	53	93	178	1·851	3·071	5·388	10·313

Factory H.I. Table 47. *Ages* 18-22

(1*st Aug.* 1916–1*st March*, 1917.)

Length of time employed	Number employed	Number Left				Percentages			
		Ill health	Other causes	Insanity	Total	Ill health	Other causes	Insanity	Total
0	97	1	10	1	12	1·031	10·309	1·031	12·371
1	58	1	3	1	5	1·724	5·172	1·724	8·620
2	150	1	—	4	5	0·667	—	2·667	3·334
3	195	—	—	—	—	—	—	—	—
4	38	—	3	1	4	—	7·895	2·631	10·526
5	63	—	4	1	5	—	6·349	1·587	7·936
6	11	—	—	—	—	—	—	—	—
7	0	—	—	—	—	—	—	—	—
Totals	612	3	20	8	31	0·490	3·268	1·307	5·065

Factory H.I. Table 48. *Ages* 23-27

(1*st Aug.* 1916–1*st March*, 1917.)

Length of time employed	Number employed	Number Left				Percentages			
		Ill health	Other causes	Insanity	Total	Ill health	Other causes	Insanity	Total
0	291	2	20	18	40	0·687	6·873	6·186	13·746
1	193	1	10	8	20	1·036	5·181	4·145	10·362
2	147	2	4	5	11	1·361	2·721	3·401	7·483
3	128	1	2	5	8	0·781	1·563	3·906	6·250
4	88	2	2	3	7	2·273	2·273	3·409	7·955
5	52	—	1	1	2	—	1·754	1·754	3·508
6	5	—	—	—	—	—	—	—	—
7	0	—	—	—	—	—	—	—	—
Totals	904	8	39	40	88	0·885	4·313	4·420	9·734

Factory H.I. Table 49. *Over* 28

(1*st Aug.* 1916–1*st March*, 1917.)

Length of time employed	Number employed	Number Left				Percentages			
		Ill health	Other causes	Insanity	Total	Ill health	Other causes	Insanity	Total
0	720	10	52	46	108	1·389	7·222	6·389	15·000
1	486	6	15	27	48	1·235	3·086	5·556	9·877
2	393	3	11	14	28	0·763	2·799	3·562	7·124
3	316	3	4	10	17	0·949	1·266	3·165	5·380
4	256	—	4	5	9	—	1·563	1·953	3·516
5	158	3	2	8	12	1·266	1·266	5·063	7·595
6	11	—	—	—	—	—	—	—	—
7	0	—	—	—	—	—	—	—	—
Totals	2,339	25	88	109	222	1·074	3·782	4·684	9·540

Factories H.1, H.2 and H.3. Table 50.—*Ages* 18–22.

Length of time, in months.	Number employed.	Numbers Left.				Percentages.			
		Ill health.	Other sufficient reason.	Insufficient reason.	Total.	Ill health.	Other sufficient reason.	Insufficient reason.	Total.
0	892	3	29	33	65	336	3·251	3·700	7·287
1	649	7	23	21	51	1·078	3·544	3·236	7·858
2	518	5	12	18	35	971	2·330	3·495	6·796
3	380	2	6	13	21	·526	1·579	2·421	5·526
4	289	2	3	7	12	·692	1·038	2·422	4·152
5	244	—	3	9	12	—	1·245	3·734	4·979
6	180	—	—	9	9	—	—	5·000	5·000
7	125	1	1	6	8	·787	·787	4·724	6·299
8	67	2	1	2	5	2·985	1·493	2·985	7·463
9	10	—	—	—	—	—	—	—	—
10	56	—	—	—	—	—	—	—	—
11	11	—	—	—	—	—	—	—	—
12	0	—	—	—	—	—	—	—	—
Totals	3,430	22	78	118	218	641	2·915	4·082	6·997

Factories H.1, H.2 and H.3. Table 51.—*Ages* 23–27.

Length of time, in months.	Number employed.	Numbers Left.				Percentages.			
		Ill health.	Other sufficient reason.	Insufficient reason.	Total.	Ill health.	Other sufficient reason.	Insufficient reason.	Total.
0	823	13	44	51	108	1·580	5·346	6·197	13·123
1	565	8	25	18	51	1·441	4·506	3·243	9·189
2	160	5	15	16	36	1·087	3·261	3·478	7·826
3	360	5	8	20	33	1·389	2·222	5·556	9·167
4	293	3	6	11	20	1·141	2·281	4·183	7·605
5	215	6	2	6	14	2·791	930	2·791	6·512
6	147	3	3	13	19	2·041	2·041	8·844	12·925
7	100	2	2	3	7	2·000	2·000	3·000	7·000
8	49	—	—	2	2	—	—	4·082	4·082
9	41	—	—	1	1	—	—	2·439	2·439
10	33	—	—	1	1	—	—	3·030	3·030
11	16	—	—	—	—	—	—	—	—
12	0	—	—	—	—	—	—	—	—
Totals	3,062	15	105	142	292	1·470	3·429	4·637	9·536

Factories H.1, H.2 and H.3. Table 52.—*Over* 28.

Length of time, in months.	Number employed.	Numbers Left.				Percentages.			
		Ill health.	Other sufficient reason.	Insufficient reason.	Total.	Ill health.	Other sufficient reason.	Insufficient reason.	Total.
0	2,018	41	145	114	260	2·032	5·699	5·600	13·331
1	1,429	24	66	68	158	1·679	4·613	4·759	11·051
2	1,064	12	40	46	98	1·031	3·436	3·952	8·419
3	921	8	24	43	75	·869	2·606	4·669	8·144
4	708	6	17	25	48	·847	2·401	3·531	6·779
5	581	3	9	26	38	·516	1·549	4·475	6·540
6	382	6	3	15	24	1·571	·785	3·927	6·283
7	265	—	3	10	13	—	1·132	3·774	4·906
8	141	—	—	6	6	—	—	4·196	4·196
9	99	—	1	1	2	—	1·010	1·010	2·020
10	91	—	—	3	3	—	—	3·297	3·297
11	47	—	—	2	2	—	—	4·255	4·255
12	0	—	—	—	—	—	—	—	—
Totals	7,848	100	278	358	736	1·274	3·542	4·562	9·378

FACTORIES H.1, H.2 AND H.3 TABLE 53—*All Ages*

Length of service	Number employed	Number leaving				Percentage			
		16 weeks	16 weeks and under 1 year	1 year and under 2 years	Total	16 weeks	16 weeks and under 1 year	1 year and under 2 years	Total
0	2,734	57	188	197	442	1·527	5·036	5·277	11·840
1	2,463	39	114	107	260	1·481	4·339	4·064	9·884
2	2,084	22	67	80	169	1·056	3·332	3·980	8·408
3	1,971	15	38	70	123	0·761	1·928	3·551	6·240
4	1,963	11	29	48	80	0·560	1·477	2·445	4·078
5	1,937	9	14	41	64	0·465	0·723	2·117	3·305
6	703	9	6	37	52	1·280	0·853	5·263	7·396
7	402	3	0	10	28	0·746	1·990	2·488	6·965
8	259	2	1	10	13	0·772	0·386	3·861	5·019
9	180	—	1	2	3	—	0·556	1·111	1·667
10	102	—	—	4	4	—	—	3·922	3·922
11	77	—	—	2	2	—	—	2·597	2·597
12	0	—	—	—	—	—	—	—	—
Totals	14,894	167	468	605	1,240	1·121	3·142	4·062	8·325

PROJECTILES TABLE 54 AGES 18–22

	Persons employed	Number leaving	Number leaving during first week	Number leaving during first month	Per cent. leaving during first month	Number leaving during first year	Per cent. leaving during first year	Number leaving during second year	Per cent. leaving during second year
H.3	1,100	32	5	9	0·82	21	1·91	7	0·64
H.2	1,200	18	3	5	0·42	12	1·00	5	0·42
H.1	1,000	14	1	3	0·30	9	0·90	4	0·40

AGES 23–27

	Persons employed	Number leaving	Number leaving during first week	Number leaving during first month	Per cent. leaving during first month	Number leaving during first year	Per cent. leaving during first year	Number leaving during second year	Per cent. leaving during second year
H.3	1,800	97	11	19	1·06	64	3·56	28	1·56
H.2	1,500	62	7	12	0·80	41	2·73	18	1·20
H.1	1,200	45	4	8	0·67	29	2·42	12	1·00

AGES 28–

	Persons employed	Number leaving	Number leaving during first week	Number leaving during first month	Per cent. leaving during first month	Number leaving during first year	Per cent. leaving during first year	Number leaving during second year	Per cent. leaving during second year
H.3	2,500	110	12	21	0·84	72	2·88	32	1·28
H.2	2,000	68	8	14	0·70	46	2·30	20	1·00
H.1	1,500	50	5	9	0·60	33	2·20	14	0·93

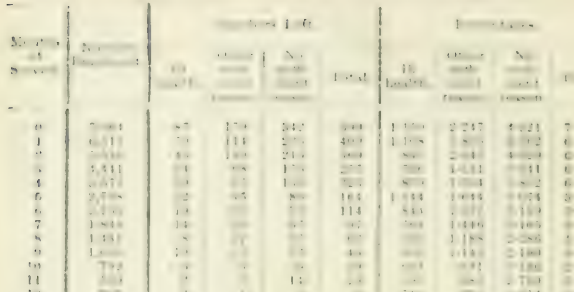
All Factories. Table 55.—*Ages* 13—17.

Months of Service.	Number Employed	Numbers Left.				Percentages.			
		Ill health.	Other suffi-cient reasons.	No suffi-cient reasons.	Total.	Ill health.	Other suffi-cient reasons.	No suffi-cient reasons.	Total.
0	2,937	17	26	155	198	579	885	5·277	6·742
1	2,515	8	29	91	122	·318	·915	3·618	4·851
2	2,237	6	29	76	105	·268	1·028	3·397	4·694
3	1,906	12	19	68	99	·620	·981	3·512	5·114
4	1,466	6	19	52	77	·360	1·140	3·121	4·622
5	1,466	8	10	38	56	·546	·682	2·592	3·820
6	1,251	4	5	31	40	·320	·460	2·478	3·198
7	1,090	2	7	14	23	·183	·642	1·284	2·110
8	989	1	2	13	16	·101	·202	1·314	1·618
9	900	5	5	19	29	·556	·556	2·111	3·223
10	800	1	2	5	8	·125	·250	·625	1·000
11	735	—	4	4	8	—	·544	·544	1·088
12	663	—	2	3	5	—	·302	·452	·754
13	634	1	3	7	11	·163	·489	1·149	1·792
14	537	—	1	9	10	—	·186	1·676	1·862
15	473	—	2	4	6	—	·423	·846	1·268
16	402	—	3	4	7	—	·746	·995	1·741
17	360	1	2	1	4	·278	·556	·278	1·112
18	304	1	—	2	3	·329	—	·657	·987
19	270	—	—	3	3	—	—	1·111	1·111
20	235	1	—	1	2	·426	—	·426	·851
21	195	—	2	4	6	—	1·026	2·051	3·077
22	145	1	—	—	1	·690	—	—	·690
23	118	—	1	1	2	—	·847	·847	1·694
24	95	1	—	—	1	1·053	—	—	1·053
Totals	22,933	76	161	605	842	·331	·702	2·638	3·672

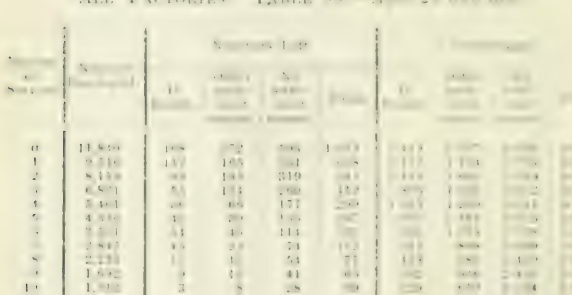
All Factories. Table 56.—*Ages* 18—22.

Months of Service.	Number Employed	Numbers Left.				Percentages.			
		Ill health.	Other suffi-cient reasons.	No suffi-cient reasons.	Total.	Ill health.	Other suffi-cient reasons.	No suffi-cient reasons.	Total.
0	14,345	135	165	542	842	·938	1·146	3·765	5·869
1	12,386	128	141	381	650	1·033	1·137	3·132	5·252
2	10,650	52	120	55	427	·514	1·183	5·414	4·210
3	9,666	55	11	264	430	·57	1·142	2·733	4·445
4	7,991	38	58	41	537	·476	1·179	3·209	5·075
5	5,860	45	85	172	300	·768	1·448	2·901	5·117
6	4,744	31	62	141	234	·649	1·308	3·162	5·119
7	3,933	12	48	146	176	·305	1·220	2·946	4·471
8	3,264	11	41	75	127	·337	1·256	2·341	3·934
9	2,449	16	15	43	74	·653	·613	1·756	3·022
10	1,953	9	15	41	66	·461	·768	2·099	3·378
11	1,289	7	12	18	37	·543	·931	1·396	2·870
12	722	2	5	10	17	·277	·648	1·385	2·302
13	617	3	2	4	9	·483	·324	·648	1·455
14	557	—	1	1	2	—	·718	·180	·898
15	542	1	3	6	10	·185	·554	1·107	1·846
16	449	—	1	1	2	—	·667	·669	1·336
17	401	—	—	1	1	—	—	·249	·249
18	312	—	1	6	10	—	·995	1·493	1·488
19	126	—	2	3	5	—	1·18	2·39	3·574
20	274	—	—	1	1	—	—	·368	·368
21	218	—	2	—	2	—	·917	—	·917
22	166	—	1	7	8	—	6·12	4·217	4·819
23	146	—	1	1	2	—	6·94	6·94	1·388
24	123	—	—	3	3	—	2·439	—	2·439
Totals	82,179	607	925	2,489	4,021	·739	1·125	3·029	4·893

All Factories—Table 57.—*Ages 23—27.*



All Factories—Table 58.—*Ages 28 and upwards.*



ALL FACTORIES—TABLE 59—*Combined Ages.*

Age last birthday.	Number Examined.	Number Rejected.				Percentages.			
		Ill health.	Other suffi-cient reason.	No suffi-cient reason.	Total.	Ill health.	Other suffi-cient reason.	No suffi-cient reason.	Total.
0	36,736	197	635	1,820	2,652	1·108	1·723	4·443	7·274
1	30,736	318	441	1,063	1,822	1·035	1·434	3·465	5·960
2	26,382	216	58	974	1,248	814	1·467	3·696	5·982
3	22,254	176	228	883	1,287	791	1·024	3·968	5·783
4	17,995	150	87	393	630	·834	1·223	3·329	5·385
5	14,469	126	248	440	737	·871	1·382	3·117	5·370
6	11,748	88	75	368	531	·749	1·141	3·119	5·009
7	9,710	42	104	264	408	·44	1·071	2·688	4·202
8	7,856	34	6	174	276	·429	·764	2·279	3·501
9	6,941	40	15	177	244	·657	·801	2·852	3·513
10	5,803	19	39	86	142	·481	·817	2·537	4·034
11	5,309	15	21	53	90	·423	·695	1·602	2·720
12	1,956	6	4	24	38	·307	·409	1·227	1·943
13	1,685	4	8	11	23	·237	·475	·653	1·365
14	1,475	—	6	11	17	—	·407	·746	1·153
15	1,325	3	6	11	20	·226	·453	·830	1·509
16	1,123	—	6	10	16	—	·534	·890	1·425
17	1,011	1	—	2	6	·099	·297	·198	·593
18	830	2	1	5	11	·241	·674	1·084	1·325
19	788	1	3	6	10	·127	·381	·761	1·269
20	668	1	1	3	5	·150	·150	·449	·749
21	531	—	4	5	9	—	·754	·94	1·695
22	402	1	1	8	10	·249	·249	1·990	2·488
23	344	—	1	3	5	—	·581	·871	1·453
24	292	1	—	—	4	·342	1·027	—	1·370
Totals	204,680	1,651	2,8[illegible]	6,[illegible]	11,[illegible]	·807	1·398	3·[illegible]	5·576

Combined Ages

	Farmers	Mer-chants	Brick-layers, Stone-masons	Carpenters	Shoe-makers	Laundry-men	Team-sters	Agri-cultural	General	Un-known	Wood-workers	Fruit Pickers	Total
Number	2,276	1,152	1,021	1,005	1,754	815	616	774	193	1,294	256	579	25,731
Male	2,217	1,092	1,007	1,003	748	169	38	112	20	1,241	141	521	11,098
Percentage	19.97	10.39	14.59	18.02	6.72	1.87	1.18	1.3	1.08	10.89	1.65	2.45	100.00

Age 28 and over

Number	1,760	1,118	1,008	1,000	454	213	93	67	51	1,118	72	13	8,113
Male	1,760	1,092	1,008	1,000	448	209	91	18	19	28	1,118	50	9	3,727
Percentage	21.42	13.31	12.41	14.18	5.73	2.85	1.1	0.7	0.3	13.66	1.07	0.19	100.00

Ages 23—27

Number	1,259	684	775	983	858	163	21	54	51	501	90	21	5,149
Male	1,259	684	775	983	848	160	23	43	18	419	83	9	2,415
Percentage	24.92	13.51	15.30	19.73	9.86	3.08	0.3	1.58	0.3	17.08	1.14	0.10	100.00

Ages 18—22

Number	2,259	1,113	1,161	1,377	378	180	91	155	90	1,393	91	81	10,374
Male	1,259	979	980	877	298	89	19	78	42	615	83	72	4,921
Percentage	21.78	10.73	12.34	13.46	2.29	1.64	.48	1.41	.08	17.85	1.02	1.16	100.00

Under 18

Number	197	241	198	185	174	21	1	8	3	280	21	193	2,095
Male	197	81	74	185	74	8	—	2	1	64	5	241	842
Percentage	18.46	8.08	9.78	18.35	7.09	.82	.08	.31	.14	12.65	.89	23.68	100.00

All L. Factories Table 61.—*Ages* 13—17.

Months of Service.	Number Employed	Numbers Left				Percentages.			
		Ill health.	Other sufficient reason.	No sufficient reason.	Total.	Ill health.	Other sufficient reason.	No sufficient reason.	Total.
0	2,460	16	25	134	175	·650	1·016	5·447	7·113
1	2,161	6	22	78	106	·277	1·017	3·604	4·898
2	1,977	7	19	69	95	·354	·961	3·490	5·311
3	1,726	14	15	52	81	·811	·869	3·013	4·693
4	1,500	5	15	42	62	·333	1·000	2·800	4·133
5	1,331	8	10	30	48	·601	·751	2·254	3·606
6	1,138	1	5	27	33	·088	·439	2·373	2·900
7	1,015	2	7	11	20	·197	·690	1·084	1·970
8	945	1	2	12	15	·107	·214	1·283	1·604
9	858	5	4	17	26	·584	·466	1·981	3·030
10	791	—	2	5	7		·253	·631	·885
11	733	—	4	4	8		·546	·546	1·091
12	663	—	2	3	5		·302	·452	·754
13	614	1	3	7	11	·163	·489	1·140	1·792
14	537	—	1	9	10	—	·186	1·676	1·862
15	473	—	2	4	6	—	·423	·846	1·268
16	402	—	3	4	7	—	·746	·995	1·741
17	360	1	2	1	4	·278	·556	·278	1·112
18	304	1		2	3	·329		·987	1·316
19	276	—	—	3	3			1·087	1·087
20	235	1	—	1	2	·426	—	·426	·851
21	195	—	2	4	6		1·026	2·051	3·077
22	145	1	—	—	1	·690	—	—	·690
23	118	—	1	2	3		·847	1·695	2·542
24	95	1	—	—	1	1·053	—	—	1·053
Totals	21,015	71	196	521	788	·337	·931	2·476	3·747

All L. Factories Table 62.—*Ages* 18—22

Months of Service.	Number Employed	Numbers Left				Percentages.			
		Ill health.	Other sufficient reason.	No sufficient reason.	Total.	Ill health.	Other sufficient reason.	No sufficient reason.	Total.
0	6,564	65	54	291	410	·990	·823	4·435	6·248
1	5,746	68	54	198	320	1·183	·940	3·446	5·569
2	5,426	40	36	132	208	·737	·663	2·433	3·833
3	5,218	26	26	94	146	·498	·498	1·801	2·797
4	5,072	21	23	73	117	·414	·453	1·439	2·306
5	4,955	24	17	67	108	·484	1·210	1·352	2·180
6	4,847	14	15	48	77	·289	1·119	2·470	3·878
7	4,770	6	11	31	48	·126	·671	1·656	2·453
8	4,722	8	8	30	46	·169	·551	1·907	2·627
9	4,676	7	4	18	29	·149	·342	1·496	2·487
10	4,647	5	8	13	26	·107	·758	1·631	2·496
11	4,621	6	8	9	23	·129	·518	·388	2·035
12	4,598	3	4	9	16	·065	·369	1·412	2·046
13	4,582	3	1	4	9	·065	·174	·648	1·287
14	4,573	—	1	1	2	—	·718	·180	·898
15	4,542	1	—	7	10	·195	·591	1·367	1·953
16	4,519	—	3	4	7	—	·687	·883	1·571
17	4,491	—	—	1	1	—	—	·249	·249
18	4,472	—	4	6	10	—	1·475	1·611	2·236
19	4,426	—	3	3	6	—	·613	·613	1·356
20	4,399	—	—	1	1	—	—	·228	·228
21	4,378	—	1	2	3	—	·114	—	·342
22	4,366	—	1	3	4	—	·343	·917	1·260
23	4,344	—	—	1	2	—	·230	·230	·460
24	4,333	—	—	—	1	—	1·153	—	1·153
Totals	99,711	374	378	1,091	1,843	·375	·379	1·094	1·848

All L Factories Table 63— Lbs 23 27

Months	Number	Number Lost				Expenses			
		Ill health	Other causes	No cause	Total	Ill health	Other causes	No cause	Total
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
Totals									

All L Factories Table 64

Months	Number	Number Lost				Expenses			
		Ill health	Other causes	No cause	Total	Ill health	Other causes	No cause	Total
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									
Totals									

All L Factories. Table 65.—*All Ages.*

Months of Service.	Number Employed.	Number Left				Per 1,000			
		Ill health.	Other sufficient reason	No sufficient reason.	Total.	Ill health.	Other sufficient reason	No sufficient reason.	Total.
0	16,864	168	184	793	1,145	9·96	1·091	4·704	6·792
1	14,147	139	143	456	740	9·83	1·025	3·223	5·231
2	12,112	103	122	350	575	8·50	1·007	2·890	4·747
3	10,122	77	73	278	428	7·61	·959	2·749	4·228
4	8,361	58	76	214	348	6·94	·789	2·560	4·162
5	7,057	66	82	185	333	9·35	1·162	2·622	4·719
6	5,798	31	48	130	209	5·35	·828	2·242	3·605
7	5,035	19	30	81	130	3·77	·596	1·609	2·582
8	4,310	17	23	84	122	3·94	·487	1·949	2·831
9	3,614	23	29	57	109	6·36	·803	1·577	2·767
10	3,122	9	14	31	54	2·88	·448	·994	1·730
11	2,498	10	14	26	50	4·00	·560	1·041	2·042
12	1,879	5	8	18	31	2·66	·426	·958	1·650
13	1,685	4	8	11	23	2·37	·475	·653	1·365
14	1,475		6	11	17		·407	·746	1·153
15	1,325	3	6	13	22	2·26	4·53	·981	1·660
16	1,129		6	10	16		·531	·890	1·425
17	1,011	1	3	2	6	·989	·297	·198	·593
18	890	2	7	9	18	2·24	·787	1·011	2·022
19	794	1	3	6	10	·126	·387	·756	1·259
20	268	1		3	4	·150		·449	·599
21	34	—	1	5	7		·753	·92	1·066
22	402	1	1	8	10	·249	·249	1·990	2·488
23	344	—	2	3	5		·581	·872	1·453
24	292	1	3	—	4	3·42	1·027	—	1·370
Totals	105,459	739	909	2,732	4,380	7·01	·862	2·591	4·151

Under 18

	Tinners	Solderers	Tinsmiths' Assistants	Stampers	Shearers	Annealers	Tinning Pots	Coppers	Japan Pots	Miscellaneous	Ages Unknown	Under Inspection	Total
Employed	301	174	310	134	52	42			338	18	1	160	1 677
Left	144	58	141	30	18	2			228	8		41	670
Percentages	20·71	9·80	19·44	7·25	3·80	1·79			27·42	1·31	·64	8·29	100·00
Ages 18—22													
Employed	1 206	414	565	776	240	60	17	2	5	19	1	1 685	4 990
Left	478	83	318	382	88	27			80	24	1	889	1 870
Percentages	24·08	7·56	18·41	10·19	4·84	1·53	·15	·01	1·68	1·26	·03	31·62	100·00
Ages 23—27													
Employed	805	270	284	254	115	66	6	6	13	19	—	749	2 295
Left	204	140	185	138	45	9	3	3	3	14	—	76	820
Percentages	19·23	13·46	14·09	17·08	5·39	1·35	·29	·32	·35	1·66	—	26·48	100·00
Age 28 and over													
Employed	681	456	742	700	340	85	7	14	5	37	—	644	3 535
Left	227	187	281	326	97	29	2	5	6	21	—	208	1 190
Percentages	18·79	12·87	21·66	14·09	8·09	2·41	·09	·53	·23	1·23	—	18·04	100·00
All Ages													
Employed	2 426	1 314	1 901	1 864	746	253	28	32	500	143	2	3 246	12 384
Left	997	427	964	876	280	68	5	10	285	64	1	705	4 380
Percentages	20·41	10·03	18·58	14·06	5·66	1·73	·17	·37	4·68	1·18	·02	23·57	100·00

All H. Factories. Table 67.—*Ages* 13-17.

Months of Service.	Number Employed.	Numbers Left.				Percentages.			
		Ill health.	Other sufficient reasons.	No sufficient reasons.	Total.	Ill health.	Other sufficient reasons.	No sufficient reasons.	Total.
0	477	1	1	21	23	·210	·210	4·403	4·823
1	351	3	—	13	16	·855	—	3·704	4·558
2	260	1	2	7	10	·385	·769	2·692	3·846
3	210	1	1	16	18	·476	·476	7·619	8·571
4	166	1	4	10	15	·602	2·410	6·024	9·036
5	135	—	—	8	8	—	—	5·926	5·926
6	113	3	—	4	7	2·655	—	3·540	6·195
7	75	—	—	3	3	—	—	4·000	4·000
8	54	—	—	1	1	—	—	1·852	1·852
9	42	—	1	2	3	—	2·381	4·762	7·143
10	9	1	—	—	1	11·111	—	—	11·111
11	2	—	—	—	—	—	—	—	—
12	—	—	—	—	—	—	—	—	—
Totals	1,894	11	9	85	105	·581	·475	4·488	5·544

All H. Factories. Table 68. —*Ages* 23-27.

Months of Service.	Number Employed.	Numbers Left.				Percentages.			
		Ill health.	Other sufficient reasons.	No sufficient reasons.	Total.	Ill health.	Other sufficient reasons.	No sufficient reasons.	Total.
0	4,418	58	114	207	379	1·313	2·580	4·685	8·578
1	3,619	44	81	124	249	1·216	2·238	3·426	6·880
2	3,140	30	75	151	256	·955	2·389	4·809	8·153
3	2,663	27	48	132	207	1·014	1·802	4·957	7·773
4	2,105	22	38	94	154	1·045	1·805	4·466	7·316
5	1,598	20	31	58	109	1·252	1·940	3·629	6·822
6	1,274	14	20	48	82	1·099	1·570	3·768	6·438
7	991	11	19	47	77	1·110	1·917	4·743	7·770
8	744	5	9	18	32	·672	1·210	2·419	4·301
9	503	4	6	16	26	·795	1·193	3·181	5·169
10	344	3	3	8	14	·872	·872	2·326	4·070
11	162	—	2	9	11	—	1·235	5·556	6·790
12	18	—	—	1	1	—	—	5·556	5·556
Totals	21,589	238	446	913	1,597	1·102	2·065	4·227	7·394

All H. Factories. Table 69.—*Unknown Ages.*

Months of Service.	Number Employed.	Numbers Left.				Percentages.			
		Ill health.	Other sufficient reasons.	No sufficient reasons.	Total.	Ill health.	Other sufficient reasons.	No sufficient reasons.	Total.
0	155	—	—	22	22	—	—	14·194	14·194
1	128	1	3	5	9	·781	2·344	3·906	7·031
2	113	2	3	11	16	1·770	2·655	9·735	14·159
3	93	—	4	10	14	—	4·301	10·753	15·054
4	73	2	—	7	9	2·740	—	9·589	12·329
5	61	—	—	6	6	—	—	9·836	9·836
6	52	—	—	4	4	—	—	7·692	7·692
7	44	—	1	5	6	—	2·273	11·364	13·636
8	36	—	—	2	2	—	—	5·556	5·556
9	28	1	1	1	3	3·571	3·571	3·571	10·713
10	13	—	—	—	—	—	—	—	—
11	4	—	—	—	—	—	—	—	—
12	—	—	—	—	—	—	—	—	—
Totals	800	6	12	73	91	·750	1·500	9·125	11·375

All H Factories Table 70.—*Ages* 18 22

Number of Employment	Number Employed	Numbers Left				Percentages			
		Ill health	Other specified causes	No specified cause	Total.	Ill health	Other specified causes	No specified cause	Total.
0	7,881	70	111	251	432	888	1·417	3·205	5·517
1	6,815	60	94	230	384	877	1·374	3·361	5·612
2	6,665	32	84	244	360	528	1·485	4·007	5·919
3	5,740	30	81	205	320	743	1·443	3·625	6·211
4	4,214	37	55	161	253	879	1·306	3·824	6·011
5	3,288	19	53	105	177	578	1·612	3·193	5·383
6	2,720	17	39	105	150	625	1·453	3·922	5·628
7	2,174	6	37	85	128	276	1·702	3·910	5·888
8	1,668	6	23	45	74	360	1·379	2·698	4·436
9	1,165	9	12	26	47	·773	1·030	2·232	4·034
10	820	5	7	22	34	610	854	2·684	4·148
11	378	2	4	9	15	529	1·058	2·381	3·968
12	36	1	—	1	2	2·778	—	2·778	5·556
Totals	42,456	398	609	1,487	2,390	·937	1·381	3·422	5·360

All H Factories Table 71. —*Ages* 28 *and over*

Number of Employment	Number Employed	Numbers Left				Percentages			
		Ill health	Other specified causes	No specified cause	Total.	Ill health.	Other specified causes	No specified cause	Total
0	7,115	115	218	390	723	1·616	3·064	5·481	10·161
1	6,666	76	125	242	443	1·344	2·249	4·279	7·832
2	4,785	60	95	223	378	1·254	1·985	4·660	7·899
3	4,056	43	73	194	310	1·073	1·822	4·843	7·738
4	3,162	35	44	120	199	1·110	1·396	3·805	6·313
5	2,393	26	29	85	130	1·087	1·212	3·570	5·268
6	1,802	23	28	83	144	1·276	1·480	4·607	7·982
7	1,394	8	17	45	70	·574	1·220	3·228	5·022
8	1,113	6	6	31	43	·534	·534	2·769	3·808
9	770	4	10	24	38	·519	1·299	3·117	4·935
10	561	1	6	22	29	·178	1·070	3·922	5·169
11	270	3	1	9	13	1·111	·370	3·333	4·815
12	23	—	—	4	4	—	—	17·391	17·391
Totals	33,140	400	655	1,482	2,537	1·207	1·976	4·458	7·655

All H. Factories. Table 72.—*All Ages.*

Number of Employment	Number Employed	Numbers Left.				Percentages.			
		Ill health	Other specified causes	No specified cause	Total.	Ill health.	Other specified causes	No specified cause	Total
0	12,196	244	444	891	1,579	1·220	2·220	4·456	7·897
1	16,627	184	303	614	1,101	1·107	1·822	3·693	6·623
2	14,493	125	209	605	1,019	·870	1·453	4·421	7·095
3	12,221	110	207	558	875	·900	1·694	4·566	7·160
4	9,706	97	141	382	620	·999	1·453	3·936	6·391
5	7,475	65	113	272	450	·870	1·512	3·639	6·020
6	6,081	57	87	242	386	·942	1·438	3·980	6·379
7	4,978	25	74	185	284	·534	1·487	3·716	6·071
8	3,625	17	41	97	155	·469	1·131	2·676	4·276
9	2,598	18	30	69	117	·718	1·156	2·754	4·665
10	1,756	10	16	52	78	·569	·911	2·961	4·442
11	816	5	7	27	39	·613	·858	3·308	4·779
12	77	1	—	6	7	1·299	—	7·792	9·091
Totals	99,899	958	1,722	4,040	6,720	·959	1·724	4·044	6·727

	Factory	Muni-tions	House-hold Work.	Servants.	Shop	Laundry.	Trans-port.	Clerical.	First Place.	Miscel-laneous.	Agri-culture.	Un-known.
Numbers	57	38	129	68	38	7	1	3	39	3	7	12
Lost	9	6	37	6	—	1	—	1	6	—	2	37
Percentages	13·02	8·68	32·74	14·60	7·50	1·58	·20	·79	8·88	·59	1·78	9·66

Ages 18–22.

Numbers	1,880	697	596	1,087	525	113	36	92	24	32	124	235
Lost	652	277	246	268	171	30	13	42	22	23	77	564
Percentages	32·33	12·44	10·74	17·30	8·89	1·84	·69	1·74	·59	·70	2·57	10·20

Ages 23–27.

Numbers	834	413	493	500	252	67	15	28	11	35	54	119
Lost	376	216	225	207	97	33	20	11	5	19	43	345
Percentages	27·39	14·24	16·25	16·00	7·90	2·26	·79	·88	·36	1·22	2·20	10·50

	Factory	Mines & Quarries	Domestic & Hotel Work	Servants	Shop	Laundry	Transport	Canal	Farm Work	Mental Defectives	Ages unknown	Total known
Examined	1,029	682	1,211	693	258	126	28	32	8	40	87	902
Left	509	208	568	275	109	62	14	19	3	29	19	466
Percentages	23·39	14·72	24·82	13·77	6·06	2·67	·80	·72	·16	·98	·79	12·82

Unknown Ages

Examined	7	8	9	7	6	—	—	1	—	—	1	—
Left	2	1	23	4	—	—	1	—	—	2	—	127
Percentages	4·84	2·06	18·49	5·67	3·09	—	·52	·52	—	1·03	·52	65·46

All Ages.

Examined	3,857	1,813	2,348	2,457	1,079	313	80	156	82	110	223	768
Left	1,608	865	1,069	765	437	126	53	73	36	73	141	1,539
Percentages	27·33	13·69	17·54	15·56	7·58	2·20	·67	1·15	·59	·92	1·82	11·54

Table 74.

Three Months' Survival Rates.

Factory.	Ages 18–22.	Ages 23–27.	Ages 28– .
L 4 .	84·16 ± ·83	81·78 ± 1·21	83·95 ± 1·06
L 5 .	93·60 ± ·74	93·12 ± ·71	89·56 ± 1·20
H 4 .	88·42 ± ·92	81·02 ± 1·81	81·65 ± 1·89
H 1 . .	82·30 ± 1·87	72·88 ± 1·92	71·24 ± 1·23
H 8 .	66·27 ± 2·54	66·84 ± 2·88	66·93 ± 2·74
H 9 ..	90·73 ± 1·46	86·81 ± 2·61	82·84 ± 1·56
L 3 .	85·75 ± ·73	81·80 ± ·88	80·17 ± ·87
H 2 . ..	84·66 ± 2·63	73·71 ± 2·34	66·56 ± 1·57
H 3 . ..	77·16 ± 1·82	73·76 ± 1·66	72·42 ± 1·14
H 5	86·80 ± 2·29		88·17 ± 1·74
H 10	85·71 ± ·82	82·70 ± ·86	84·14 ± ·78
L 1 . ..	84·32 ± ·74	81·47 ± 1·48	83·42 ± ·97
H 6	87·91 ± ·61	86·80 ± ·95	78·50 ± ·71
L 2	76·45 ± 1·05	74·81 ± 1·16	80·82 ± ·80
H 7	82·65 ± ·80	76·55 ± ·70	78·65 ± ·92
L 8	74·70 ± 2·06		
L 6	70·29 ± 2·77	64·70 ± 3·68	71·87 ± 2·26
L 7 ...	95·34 ± ·78	93·92 ± 1·46	87·78 ± 1·88

Table 75.

Nine Months' Survival Rates.

Age Group.	L.	H.	Difference.
18–22 ...	67·55 ± ·52	59·64 ± ·49	7·91 ± ·71
23–27 ...	65·16 ± ·76	51·96 ± ·68	13·19 ± 1·02
28– ...	66·59 ± ·59	52·45 ± ·54	14·14 ± ·80

Table 76.

Nine Months' Illness Survival Rates.

	Factories H.	Factories L.	Difference.
Ages 18–22 ...	94·40 ± ·24	93·04 ± ·30	1·36 ± ·38
Ages 23–27 ...	90·72 ± ·45	88·71 ± ·45	2·01 ± ·63
Ages 28– ...	93·60 ± ·36	91·67 ± ·35	1·93 ± ·50

Table 77.

Factory.	Average Weekly Hours (day-shift) including Overtime.	Three Months' Survival Rates. (Ages 28– .)
L.1	43·5	83·02
L.2	43·5	80·92
L.3	52·5	86·07
L.8	55·3	—
L.7	60·5	87·78
L.4	61·8	83·95
L.5	61·8	89·50
L.6	63·5	74·87
H.6	44·0	78·50
H.9	45·0	83·84
H.10	49·0	81·01
H.1	53·0	71·24
H.2	53·0	66·56
H.5	53·5	88·67
H.3	54·0	72·32
H.8	56·3	66·93
H.4	62·0	81·65
H.7	66·0	75·65

Factories H.4, H.10, L.3. Table 78.

Civil state.

	Married.	Single.	Widows.	Total.	Percentage Married
Under 22	243	3,856	4	4,103	5·92
23–27	536	1,358	15	1,909	28·08
Over 28	1,497	1,358	104	2,959	50·59

Factory L.3.

Table 79.—*Ages* 18–22 (*1st Sept.*, 1916—*1st Sept.*, 1917.)

Months of Service.	Number Employed.	Numbers Left.				Percentages.			
		Ill Health.	Other Sufficient Reason.	No Sufficient Reason.	Total.	Ill Health.	Other Sufficient Reason.	No Sufficient Reason.	Total.
0	1,206	9	3	45	57	·746	·249	3·731	4·726
1	970	18	2	36	56	1·855	·206	3·711	5·773
2	847	8	9	21	38	·945	1·063	2·479	4·486
3	740	6	5	17	28	·811	·676	2·297	3·784
4	635	6	7	14	27	·945	1·102	2·205	4·252
5	598	11	9	25	45	1·839	1·505	4·181	7·525
6	539	8	9	26	43	1·484	1·670	4·824	7·978
7	456	1	1	10	12	·219	·219	2·193	2·632
8	387	4	1	12	17	1·034	·258	3·101	4·393
9	307	1	—	5	6	·326	—	1·629	1·954
10	254	1	—	4	5	·394	—	1·575	1·969
11	129	1	—	2	3	·775	—	1·550	2·326
12	—	—	—	—	—	—	—	—	—
Totals ...	7,068	74	46	217	337	1·047	·650	3·070	4·768

Factory II.6.

Table 80.—*Under* 22 (1*st July*, 1916—1*st July*, 1917).

Machine Number	Number Employed	Number Left				Percentages			
		13 Weeks.	Other Subsequent Periods.	Not Subsequently Employed.	Total.	13 Weeks.	Other Subsequent Periods.	Not Subsequently Employed.	Total.
0	1,105	24	8	85	97	1·758	·511	2·408	4·782
1	1,173	25	11	23	87	1·978	·852	1·891	4·167
2	1,184	12	7	23	43	1·014	·591	1·945	3·631
3	1,087	9	13	58	80	·828	1·196	5·336	7·360
4	993	13	9	10	32	1·309	·644	1·007	3·222
5	737	8	9	17	34	1·101	1·221	2·308	4·611
6	615	4	3	15	22	1·951	·162	2·439	4·552
7	847	4	10	9	23	·354	1·181	1·061	2·716
8	475	—	3	8	11	—	·632	1·684	2·316
9	185	4	2	4	10	2·162	1·081	2·162	5·405
10	284	—	1	11	12	—	·352	3·873	4·225
11	118	—	—	6	6	—	—	5·085	5·085
12	1	1	—	—	1	100·000	—	—	100·000
Totals	8,009	108	87	295	490	1·349	·920	2·477	4·897

APPENDIX II.

Note on Errors of Sampling

When we desire to know whether a set of observations either (*a*) effectively obeys some assumed law or, (*b*), merely gives results in sensible agreement with those of some other set of observations, we must ascertain whether any divergence between theory and practice in the former case, or between the two practical experiences in the latter case, is or is not greater than might be expected often to occur by virtue of those chance fluctuations which occur when samples small, relatively to the populations from which they come, are our only means of information.

Problem (*a*) has been solved by Professor Karl Pearson in a series of admirable researches, dating from 1900.

If we have a distribution into classes :—

Group.	Observed Frequency.	Theoretically Expected Frequency.
A_0	n_0	m_0
A_1	n_1	m_1
.	.	.
.	.	.
A_n	n_n	m_n

Pearson showed that the probability of chance fluctuations leading to any observed divergence between theory and observation was a function of χ^2 where :— $\chi^2 = S \frac{(n - m)^2}{m}$

What function depends upon the form of the group standard deviations and error correlations ? Pearson has supplied the necessary modifications for most schemata of statistical importance.

Problem (*a*) is accordingly solved. Problem (*b*), however, is of more frequent occurrence in ordinary statistical practice. No theoretical law can be defined, but the significance of a divergence between two samples has to be gauged. For this purpose the above-mentioned method is widely utilised. For instance, in two recent papers (*Biometrika*, 1916, XI, pp. 146-158 and 159-184) Pearson and Tocher employ this criterion to determine whether two samples of population, for each of which the numbers exposed at ages and the deaths at ages are, respectively a_0, a_1 &c., d_0, d_1 &c., a'_0, a'_1 . . &c., d'_0, d'_1 &c., differ significantly with regard to death-rates. It is assumed that the "theoretical" death-rate of persons in the s^{th} age class is

$$\frac{d_s + d'_s}{a_s + a'_s}$$

i.e., that it is the value obtained by combining the two sets of data.

Making this assumption it can be shown that :—

$$\chi^2 = S \left\{ \frac{(a_s\ a'_s - N : N')^2}{a_s\ a'_s\ N : N'} \left(\frac{d_s}{a_s} - \frac{d'_s}{a'_s} \right)^2 \right\} \Big/ \left\{ (d_s + d'_s) \left(1 - \frac{d_s + d'_s}{a_s + a'_s} \right) \right\}$$

N and N' being the numbers of observations.

It is also pointed out that the ratio $\frac{s_1 s'_1}{(s_1 + s'_1)^2} \cdot \frac{N + N'}{N N'}$ will not usually differ much from unity, so that :—

$$\chi^2 = N \frac{s_1 \, s'_1 \left(\frac{s_1}{a_1} - \frac{s'_1}{a'_1} \right)^2}{(s_1 + s'_1) \left(1 - \frac{s_1}{a_1 + a'_1} \right)}$$

is approximately equal to χ^2

The probability that the two sets of observations have been drawn from a common source is then obtained by entering χ^2 with $n = 1$ the number of constants that are in the published tables for testing goodness of fit and finding the appropriate value of P (see Tables for Statisticians and Biometricians, pp. 26–28).

The weak point in the assimilation of the actual conditions p_1 to the *a priori* conditions π_1 is a difficulty noted in the manner from which the above results are found. Pearson and Tocher (*op. cit.*, pp. 173–4) show that, if quantities like δ_1 and δ'_1 are approximately normal in distribution then $\rho_1 = \frac{\delta_1 + \delta'_1}{s_1 + s'_1}$ is a close approximation to that value of ρ_1 which will make χ^2 as small and consequently P as large as possible.

As Yule and the writer have pointed out (*Proc. Roy. Soc. Med.*, 1915, VIII, *Sect. Hygiene*, pp. 117 *et seq.*), a practical consequence is that although samples compared by the test and on its basis, deemed to be discontinuous may certainly be so regarded, the converse is not true. The theoretical considerations involved are of considerable interest, and will be developed at length in a mathematical paper by Yule and the writer, part of which is completed. In the present connection other difficulties are of more importance. Thus although the use made of Pearson and Tocher's method in Table 28 of this report is quite defensible there are certain objections.

The fundamental data are :—

Ex-posure-free Interval	Number at Risk		Survival Rate	Death-Rate
I_0	n_0	p_0	$\frac{n_0 - f_0}{n_0} = Q_0$	$1 - Q_0 = P_0$
I_1	$n_0 - f_0 + r_0 = n_1$	p_1	$\frac{n_0 - f_0 - s_0}{n_0 - f_0 + r_0 - s_0} = Q_1$	$1 - Q_1 = P_1$
I_2	n_1	p_2	$\frac{n_0 - \sum_0^1 s - \sum_0^1 f}{n_0 - \sum_0^1 s - \sum_0^1 f + r_1 - s_1} = Q_2$	$1 - Q_2 = P_2$

Variations of survival (or "death") rates in individual periods are influenced by the system of waiting for attention. Were no absentees struck off the list within half a time unit, then "deaths" are properly credited. If a factory posts cripples thus to sort out. For instance, let the state of affairs in two factories be as follows :—(1) engaged 1,000, of whom 100 left within a few days. So others left after a monthly service

and before completing the second month. Suppose one factory writes off its losses at once, we have :—

	n	p	Q	P
t_0	1,000	100	900	·100
t_1	900	50	944	·056

Suppose the other factory does not write off any losses until the absentee's name has been on the books at least a month, its record will run :—

	n	p	Q	P
t_0	1,000	0	1·000	·000
t_1	1,000	150	850	150

The number of survivors at the end of the second month is in each the same ; the rates of loss for the separate months different. But what is really interesting is precisely the number of survivors at the end of a period such as three months, because this gives us the proportion of entrants actually reaching a stage of normal productivity. Differences in the method of reaching this proportion of survivors, which would be emphasised by the χ^2 test, may very often have no real significance, be mere peculiarities of book keeping. Of course, in the particular examples chosen in the text to exemplify the method, thus source of disturbance was known to have been absent, while under no circumstances is it likely to involve such extreme consequences as indicated in the imaginary case. Indeed the rule, where any is found, is not that losses are only struck out after a definite period from entry, but that the absentee is only removed from the list when her absence exceeds a certain number of weeks. The effect is, in theory, merely to cause a uniform transfer of "deaths" from one group to the next. In practice, however, the transfer is much concentrated upon the early, especially upon the first, exposure group. Unexplained absences prior to leaving become less and less common with length of service. As our data chiefly relate to early months of service, I have thought it well to make use of the survival method for comparative purposes, and now pass to consider its probable error.

We have :—

$$s_s = Q_0 \cdot Q_1 \cdot \ldots \cdot Q_{s-1}$$

s_s being the proportion surviving at the end of the s^{th} exposure.

Taking logarithms, and differentiating, we have :—

$$\frac{\delta s_s}{s_s} = \frac{\delta Q_0}{Q_0} + \frac{\delta Q_1}{Q_1} + \ldots \frac{\delta Q_{s-1}}{Q_{s-1}}$$

Hence :—

$$\frac{\sigma^2 s_s}{s_s^2} = \frac{\sigma^2 Q_0}{Q_0^2} + \ldots \frac{\sigma^2 Q_{s-1}}{Q_{s-1}^2} + 2 \Sigma \sigma_{Q_m} \sigma_{Q_{m'}} r_{Q_m Q_{m'}} \ldots \quad (1)$$

But $\frac{1}{Q_m^2} \cdot \sigma^2_{Q_m} = \frac{P_m q_m}{n_m Q_m}$ and *assuming* $r_{Q_m Q_{m'}} = 0$

(1) becomes :—

$$\sigma^2_{s_s} = s_s^2 \left| \Sigma \frac{P_m q_m}{n_m Q_m} \right| \quad \ldots \quad (2)$$

If $k_0 = k_1 \ldots k_{s-1} = 0$, i.e., all those existing at the close of the observation period, were at risk throughout, $n_0 Q_0 = n_1 \ldots n_{s-1} = n_{s-1} Q_{s-1}$ and (2) becomes :—

$$\frac{q^2_{s-1}}{n^2_0} \left| \frac{p_0}{n_0 q_0} + \frac{p_1}{q_0 p_1} + \ldots \frac{p_{s-1}}{q_{s-2} q_{s-1}} \right| = \frac{q^2_{s-1}}{n^2_0 n_0 q_0} \left\{ p_0 q_1 p_2 \ldots + \ldots p_{s-1} (n_0 q_0 \ldots) \right\} \quad (3)$$

Since $q_m = n_m - p_m$

Now writing $q_m : - q_m$ for f_m and reducing, (3) becomes —

$$\frac{q_{s-1}(n_0 - s_{s-1})}{n^2_0} \quad . \quad (4)$$

This is the familiar expression for the square of the standard deviation of the proportion of successes in n_0 trials, where $q_{s-1} = p_{s-1} = p_0$.

(2) is a valid expression, on the assumption stated, for the general case. But the assumption may very properly be questioned. If the different rates are on the average negatively correlated, which would be the case when losers are selective, the poorer workers being weeded out earlier, (2) is too large. If there be positive correlation, i.e. all the rates increased or diminished by some common factor such as an epidemic or changes in the hygienic conditions, heartening or harsh, &c., (2) is too small. We have no means of evaluating the correlation and (2) has been adopted in the text examples. Frankly it is but a rough guide, although the best we can use.

Printed under the authority of His Majesty's Stationery Office
By Sir Joseph Causton & Sons, Ltd., 8, Eastcheap, London, E.C. 3

NATIONAL HEALTH INSURANCE.

MEDICAL RESEARCH COMMITTEE.

I.- A report upon the Seasonal Outbreak of Cerebro-spinal Fever in the Navy at Portsmouth, 1916-1917.

II.--The treatment of Cerebro-spinal Meningitis by Anti-meningococcus Serum at the Royal Naval Hospital, Haslar, 1915-16-17.

LONDON
PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE

To be purchase[illegible] through any Bookseller or directly from
H.M. STATIONERY OFFICE at the following addresses
Imperial House Kingsway London W.C. 2 and 28 Abingdon Street London S.W. 1
or Edinburgh 120 George Street Manchester 23 St Andrew's Crescent Cardiff
or from E. PONSONBY Ltd. 116 Grafton Street Dublin

1918.

Price 2s 6d *net*

MEDICAL RESEARCH COMMITTEE.

The following publications relating to the work of the Medical Research Committee can be purchased through any bookseller, or directly from H.M. Stationery Office at the following addresses: Imperial House, Kingsway, London, W.C. 2, and 28 Abingdon Street, London, S.W. 1; 37 Peter Street, Manchester; 1 St. Andrew's Crescent, Cardiff; 23 Forth Street, Edinburgh; or from E. Ponsonby, Ltd., 116 Grafton Street, Dublin.

First Annual Report of the Medical Research Committee. 1914-1915. (Cd. 8501.) Price 3d., post free 4d.

Second Annual Report of the Medical Research Committee, 1915–1916. (Cd. 8299.) Price 3½d., post free 5d.

Third Annual Report of the Medical Research Committee. (Cd. 8825.) Price 6d. post free 7d.

Special Report Series.

No. 1. First Report of the Special Investigation Committee upon the Incidence of Phthisis in relation to Occupations. The Boot and Shoe Trade. Price 3d., post free 4d.

No. 2. Report of the Special Advisory Committee upon Bacteriological Studies of Cerebro-spinal Fever during the Epidemic of 1915. Price 6d. post free 7½d.

No. 3. Bacteriological Studies in the Pathology and Preventive Control of Cerebro-spinal Fever among the Forces during 1915 and 1916. Price 1s. 6d., post free 1s. 8½d.

No. 4. Reports upon Investigations in the United Kingdom of Dysentery cases received from the Eastern Mediterranean.

I. Amœbic Dysentery and the Protozoological Investigation of Cases and Carriers. Price 1s., post free 1s. 2d.

No. 5. II. Report upon 878 Cases of Bacillary Enteritis. Price 1s. 6d., post free 1s. 8d.

No. 6. III. Report upon Recovered Cases of Intestinal Disease in the Royal Naval Hospital, Haslar, 1915–16.

IV. Report upon combined Clinical and Bacteriological Studies of Dysentery Cases from the Mediterranean. Price 1s. 6d., post free 1s. 8d.

No. 7. V. Report upon 2,360 Enteritis "Convalescents" received at Liverpool from various Expeditionary Forces. Price 2s., post free 2s. 2½d.

No. 8. Report upon Soldiers returned as Cases of "Disordered Action of the Heart" (D.A.H.), or "Valvular Disease of the Heart" (V.D.H.). Price 1s., post free 1s. 1½d.

No. 9. A Report upon the use of Atropine as a Diagnostic Agent in Typhoid Infections. Price 1s., post free 1s. 1½d.

No. 10. The Mortalities of Birth, Infancy, and Childhood. Price 1s. 6d., post free 1s. 8d.

No. 11. The Causation and Prevention of Tri-nitro-toluene (T.N.T.) Poisoning. Price 1s., post free 1s. 2d.

No. 12. The Classification and Study of the Anærobic Bacteria of War Wounds. Price 2s., post free 2s. 2½d.

No. 13. An Enquiry into the Composition of Dietaries, with Special Reference to the Dietaries of Munition Workers. Price 3d., post free 4½d.

No. 14. Reports of the Special Committee upon the Standardization of Pathological Methods.

No. 1. The Wassermann Test. Price 3d., post free 4½d.

No. 15. A Study of 1,300 Convalescent Cases of Dysentery from Home Hospitals: with special reference to the Incidence and Treatment of Amœbic Dysentery Carriers. Price 6d., post free 7d.

No. 16. A Report on the Causes of Wastage of Labour in Munition Factories. Price 1s. 6d., post free 1s. 7½d.

No. 17. I. A Report upon the Seasonal Outbreak of Cerebro-spinal Fever in the Navy at Portsmouth, 1916–1917.

II. The Treatment of Cerebro-spinal Meningitis by Anti-meningococcus Serum at the Royal Naval Hospital, Haslar, 1915–16–17. Price 2s. 6d., post free 2s. 9d.

The following is published under the direction of the Medical Research Committee by Messrs. Longmans, Green & Co., 39, Paternoster Row, London, E.C. 4.

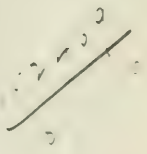
Milk and its Hygienic Relations. by Janet E. Lane-Claypon, M.D., D.Sc. (Lond.). Price 7s. 6d. net.

NATIONAL HEALTH INSURANCE.

MEDICAL RESEARCH COMMITTEE.

I.—A Report upon the Seasonal Outbreak of Cerebro-spinal Fever in the Navy at Portsmouth, 1916-1917.

II.—The treatment of Cerebro-spinal Meningitis by Anti-meningococcus Serum at the Royal Naval Hospital, Haslar, 1915-16-17.



(Approved for publication by the Medical Research Committee, December 21st, 1917.)

Medical Research Committee

(National Health Insurance.)

The Hon. Waldorf Astor, M.P. (*Chairman.*)

The Right Hon. Christopher Addison, M.D., M.P.

The Viscount Goschen, C.B.E. (*Treasurer.*)

C. J. Bond, C.M.G., F.R.C.S. (Hon. Colonel).

A. K. Chalmers, M.D., D.P.H. (Lieut.-Colonel R.A.M.C. (T.).)

Professor William Bulloch, M.D., F.R.S.

Professor F. G. Hopkins, D.Sc., F.R.S.

Colonel Sir William Leishman, K.C.M.G., C.B., F.R.S.

Professor G. R. Murray, M.D., F.R.C.P. (Major R.A.M.C. (T.).)

Sir Walter M. Fletcher, K.B.E., M.D., F.R.S. (*Secretary.*)

INTRODUCTION.

The present detailed report upon cerebro-spinal fever as it affected the Navy during the years 1915, 1916 and 1917, may be read in conjunction with the work for the Army carried out under the direction of Dr. M. H. Gordon, Hon. Lt.-Col. R.A.M.C.

By arrangement with the Medical Department of the Admiralty, Dr. Basil Hilden, in the employment of the Medical Research Committee, was sent to the Royal Naval Hospital at Haslar in 1915, and took charge of the pathological laboratory. He was subsequently granted the honorary rank of Staff Surgeon R.N.V.R. With the assistance of Dr. S. L. Baker, formerly working in the bacteriological laboratory of the London Hospital, now serving as Temporary Surgeon R.N., and appointed to the staff of the R.N. Hospital at Haslar, he was able not only to cope with the great increase of pathological work arising out of the war but also to arrange for a close study of the seasonal outbreaks of cerebro-spinal fever. The work has been greatly facilitated by the unstinted supply of materials and assistants by the Medical Department of the Admiralty.

The scheme of the investigation had to be adjusted to regulations already existing, for which Dr. Hilden was not responsible, and for this reason practical conclusions upon matters peculiar to the Navy are not drawn in this place. The existence of these regulations has however given him a unique opportunity for investigating a number of epidemiological problems of general interest which could hardly be worked out except in such a relatively small community strictly under control, as is found in the Navy at Portsmouth.

The report by Staff Surgeon Hilden and Surgeon Baker contains observations on the biological characters of the meningococcus, its viability in culture, and resistance to desiccation and cold. The results of investigation by the agglutination and agglutinin absorption test of meningococci isolated from cases of cerebro-spinal fever at Haslar are next described, and the grouping of these micro-organisms into one or other of four serologically distinct types is discussed. The authors feel justified in supporting Gordon's claim that practically all meningococci which have been found to be capable of producing cerebro-spinal fever can be demonstrated to belong to one of his four groups (p. 191). From this, as they point out, it must follow that practically all cases which cannot be shown to fall into one or other of these four groups are incapable of producing cerebro-spinal fever. The examination of work practically carried out on behalf of the Committee is of much practical importance for both in the Navy and in the Army the identification and segregation of meningococcus "carriers" is one of the chief measures in use at the present time to check the spread of cerebro-spinal fever.

The differentiation of the meningococcus into four distinct types has been followed throughout the researches described in the present report, and these observations are not only valuable for comparison with those already published by the Committee in Report No. 3 on the subject, with which they are not always in agreement, but also supply much new information. In the light of these researches reference must be made to the recent researches of the four types of meningococci and the "carriers" of each type.

The authors have had the experience of examining the cerebro-spinal exudation of no less than 701 cases (see text), on the average during the past two years, and this has afforded them an opportunity for many observations on the course and pathology of the disease. They have

B2100 Wt. 29654 7/18. 1500. 7/18. Sp. J. & S. Gp. 32.

I.—A REPORT UPON THE SEASONAL OUTBREAK OF CEREBRO-SPINAL FEVER IN THE NAVY AT PORTSMOUTH, 1916–1917.

By P. Fildes, M.B., B.C., Cantab.

(Assistant Bacteriologist to the London Hospital. Hon. Staff-Surgeon, R.N.V.R.),

AND

S. L. Baker, M.R.C.S., L.R.C.P.

(Temporary Surgeon, R.N.)

(From the Laboratory, R.N. Hospital, Haslar).

CONTENTS.

PAGE

I.—Introduction 7

II.—The Biological Characters of the Meningo-[illegible] ... 8

1. Morphology 8

(a) *In the Cerebro-Spinal Fluid* 8

(b) *In Cultures* 8

(c) *"Pleomorphism"* 9

2. Cultural Requirements 9

3. Characters of Cultures 10

(a) *On Horse-ascites Serum Agar* 10

(b) *On Ordinary Meat Agar* 10

(c) *In Meat Broth* 10

4. Resistance to Deleterious Influences 10

(a) *Drying* 10

(b) *Variability in Culture* 11

(c) *Cold* 12

5. Agglutination 12

(a) *The Influence of Meningococcal Group by Agglutination* 12

(b) *Grouping Cerebro-Spinal Fluid Strains into Types* 14

(c) *Grouping into Types by Absorption of Agglutinin Tests* 16

(d) *Variations in Agglutinability* 20

6. Fermentation Tests with Cerebro-Spinal Fluid Strains ... 22

III.—Cases of Cerebro-Spinal Fever 24

1. The Bacteriological Diagnosis of Cerebro-Spinal Fever 24

(a) *Examination of the Cerebro-Spinal Fluid* ... 24

(b) *Examination of Pharyngeal Swabs for Agglutinins* ... 25

(c) *Examination of Pharyngeal Swabs for Meningococci* 26

2. Number and Bacteriological Type 27

3. Distribution 27

4. The Effect of Age and Length of Service 29

5. Seasonal Incidence 30

6. The presence of Meningococci in the Throats of Cases ... 31

(a) *During the onset of Symptoms* 31

(b) *During the course of Symptoms* 33

IV.—Meningococcal Carriers 34

1. Meningococcal Strains of Meningococci 35

(a) *Agglutination Reactions and Absorption Tests* ... 35

(b) *Fermentation Tests* 40

(c) *Opsonic Content* 42

PAGE

2. The progress of Meningococci in the Nasopharynx ... 42
   a) *The Periods of the Transmission of the Various Types of Disease* ... 43
   b) *The Periods of the Transmission of Mass Infection* ... 46
   c) *The Acquisition and Transmission of Carriage* ... 47
3. A comparison between the type of Cases occurring during and that found in the Nasopharynx of Contacts ... 48
4. The Length of Time Carriers remain Positive ... 50
5. The relation between the Type of Cases and the Length of Time Carriers remain Positive ... 52
6. Long Detection of Carriers leading to a change in the type of the Meningococcus infecting the Nasopharynx ... 54
7. Antagonism between the various types of Meningococci in the Nasopharynx 57
8. The Pathogenicity of the various types of Meningococci in the Nasopharynx 57
9. The Length of Time during which a Carrier may be Negative and yet Relapse 58
10. The Treatment of Carriers 60
11. The importance of Cerebro Spinal Fever as a Measure of Carriers 64
12. The relation of the case of Cerebro Spinal Fever to the Positive Contacts and Secondary Cases 66

V.—The Epidemiology of Cerebro Spinal Fever 68

1. The Meningococcus Group of Gram-negative Cocci ... 68
2. The Meningococcus as a Normal Inhabitant of the Throat, subject to seasonal waves of activity 70
3. The relation between the Seasonal Outbreak of Disease Incidence and the Outbreak of Cerebro Spinal Fever ... 70
4. The Mechanism of Infection in the Case from a High Throat Rate in the Population 72

VI.—Treatment 75

1. The Examination of the Cerebro Spinal Fluid 75
2. The Investigation of Carriers 75
3. Culture Media 76
   a) *The Preparation of Serum Media* 76
   b) *The Preparation of Serum Ascitic Fluid* 77
   c) *Medium for Throat Cultures* 77
   d) *Medium for general Purposes* 78
   e) *The Culture of Meningococci on the Medium* 78
   f) *The Preservation of Serum in the Medium* 78
   g) *Meat Contents* 78
   h) *Medium for Transporting Specimens* 79
4. Agglutination Reactions 79
   a) *Sera Employed* 79
   b) *Preparation of Agglutinating Serum* 79
   c) *Preparation of Suspensions for Agglutination* 80
   d) *Temperature of the Test* 80
   e) *Reading the Results* 81
   f) *The Effect of Age on the Suspension* 81
   g) *The Effect of Heat and Carbolic upon the Agglutinating Titre of the Sera* 81
   h) *Absorption Experiments* 82
5. Absorption of Agglutinins Tests 82
6. The use of Meningococcal Vaccines as Therapeutic Agents for Diagnostic Purposes 86

CHARTS I–VI ... ... following page 87

I.—Introduction.

This report deals with the bacteriology and epidemiology of the outbreak of cerebro-spinal fever in the Navy, at Portsmouth, during the "season" 1916-17.

The actual investigation of cases of the disease is, under present conditions, but a minor matter. The number of these is small, and essential requirements may be satisfied in a few minutes. During the past few years, however, the introduction of the "carrier" concept has led in the Navy to the framing of a series of regulations, the carrying out of which occupies much of the time of the available bacteriologists.

In addition to the ordinary examination of contacts of a case, an attempt is made to prevent the introduction of carriers into the Navy altogether by examining every "new entry" at the depots.

This order, of course, necessitates the examination of thousands of men throughout the year at each depôt, and the consequent segregation of several hundreds of men in isolation camps, in some cases, for months. These isolated carriers are a further heavy tax on the resources of the naval laboratories, since every one is examined once a week until they have been demonstrated to be free from meningococci for a certain time.

We do not propose to attempt to estimate the probable value of these regulations as carried out in practice, but to point out that they afford a unique opportunity for throwing light on many of the problems associated with cerebro-spinal fever.

The examination of the new entries has enabled us to hold a census of meningococcus carriers throughout a whole year. Further, it has given us a preliminary insight into the state of the population in which the cases of disease subsequently developed. In many instances we had already examined the cases themselves, and their contacts before the onset of the disease and thus have been able to obtain evidence as to the mechanism of infection in these cases.

The demonstrated carriers were removed to a special camp and were directly under our observation, while the cases themselves were admitted to this hospital and thus were still available for investigation. A clinical account of these cases, by Staff Surgeon C. P. Adshead, R.N., accompanies this report.

It will be recognised that we have had an excellent opportunity to observe from every side a small outbreak of the disease in a definite compact population fully under control. From the text it will be obvious that we have received the cordial assistance of the Medical Officers attached to the various establishments concerned. In particular we should like to acknowledge that Surgeon-General G. Welch, C.B., R.N., has supported our work in every way. We are also much indebted for extensive personal assistance to the Principal Medical Officers (present and past) at the Royal Naval Barracks, Portsmouth, namely, Deputy

Surgeon-General W. Bell, M.V.O., R.N., and Fleet Surgeon T. T. Jones, R.N. For information relating to the Marine Establishments at Forton and Eastney we have to thank Fleet Surgeon A. E. Bashall, C.V.O., R.N., and Fleet Surgeon J. Mearns, C.B., R.N.

In carrying out the work the general routine adopted has been as follows:—

We have swabbed the throats of, on the average, 270 new entries every week throughout the year. From the macroscopic appearance of the colonies some of these are reported "doubtful" in twenty-four hours. The men are then isolated in their barracks until the final report is received. If this is "positive" they are removed to a special isolation camp, where they inhabit different sections according as they are, for the moment, positive or negative. They are subjected to various forms of treatment and swabbed every week, but are not allowed back to duty until they have been negative for three weeks.

Upon a case of the disease being reported "positive" from Haslar, the "close" contacts are removed to the isolation camp, where they remain for ten days if found to be negative. If positive they are treated like ordinary carriers. The "remote" contacts are not isolated, but are swabbed, and any "positives" removed to the isolation camp.

The work has required the swabbing of many thousands of throats, and this task was almost entirely undertaken by Mr. W. E. Thompson, M.Sc., Cornell. We are further indebted to Mr. Thompson for assistance in experimental work.

The following paper is not intended to give a complete account of the bacteriology of cerebro-spinal fever, but refers only to points which are in dispute.

II.—The Biological Characters of the Meningococcus.

1. *Morphology.*

(a) *In the cerebro-spinal fluid.*—Several instances have been met with in which the typical intracellular diplococcus has been present in large numbers, filling many of the cells and giving a film identical in appearance to that obtained from a case of acute gonorrhœa. This, however, is not the usual picture. As a rule the cocci are sparsely scattered, many being single, and few, if any, extracellular organisms can be found.

The cocci stain fairly well with the ordinary basic dyes, but particularly well with carbol thionin. They are uniform in size, and clumps are sometimes seen.

(b) *In culture.*—Films made from a culture of the meningococcus have, as a rule, a fairly typical appearance: the cocci are irregular in size, many large bloated organisms being scattered about among the smaller specimens. These giant meningococci usually stain more intensely than the smaller ones. Aggregation into clumps is another common characteristic; these form small irregular masses in which it is in places difficult to distinguish

the individual cocci. Scattered about among these clumps are often seen large numbers of tetrads, the whole producing a very characteristic microscopic field. Although the above appearances may be said to be typical, it is not uncommon to grow Gram-negative cocci from the cerebro-spinal fluid with none of these characters, they being even in size and staining and forming no clumps. These, nevertheless, prove to be meningococci on agglutination.

(c) *Pleomorphism.*—Although the assertions of Hort and his co-workers on the subject of a pleomorphism of the meningococcus appear to persist in spite of a generally adverse criticism, we ourselves have failed to substantiate them in any way. We have cultivated in stock about 150 strains of meningococci from the cerebro-spinal fluid and naso-pharynx, in some cases for as long as twelve months, and have failed to observe any change in the appearance of these cocci from the beginning to the end.

It is true that bacteria other than meningococci can sometimes be isolated, together with the meningococcus, from the cerebro-spinal fluid. Such bacteria may have actually infected the fluid *in vivo*, but usually, we think, they find their way in as contaminations during lumbar puncture. All of these accidents are of course intercepted by incubating the fluid or by using liquid culture media especially those containing serum. The conclusion is inevitable that Hort's "pleomorphism" is capable of some such simple explanation.

2. *Cultural Requirements.*

In general, the chief characteristic of the growth of the meningococcus on ordinary media is its variability. On one occasion it may be excellent, and upon subculture into a similar medium it may fail entirely. According to Miss Jordan Lloyd this phenomenon is due to an absence of a "vitamine" in the unsuccessful medium. Upon first isolation the cocci will not develop unless this "vitamine" is present, and it is usually derived from nasal mucus, pus or blood. This latter is suggested as the most convenient form in which to add "vitamine" to a medium.

We had already adopted the technique of adding small quantities of laked blood to our medium from analogy to blood agar which was always looked upon as a good medium, and we found that this addition entirely did away with the phenomenon of batches of cultures failing to grow.

In addition to a small quantity of blood the meningococcus requires, for satisfactory growth, a proportion of albuminous material. We have always used serum, and although a small quantity such as 5 per cent. is good a more copious growth is obtained by using as much as 25 per cent., and since a copious growth is particularly required for agglutination purposes we use this proportion as a routine. We refer to our medium as haemoglobin serum agar or Hb serum agar.

3. *Characters of Cultures*

(a) *On H5 serum agar.* — A discrete colony of the meningococcus, after twenty-four hours growth, is from 2 to 3 mm. in diameter and perfectly round. The colony is slightly raised and rounded in section without a central nipple. Viewed against a dark background it is of a bluish, pearly grey colour and semi-opaque. Against a light background, however, it is transparent but not quite clear; in fact some strains exhibit a relative degree of opacity.

A run or spreading edge often develops in two or three days if the medium is moist, and in old cultures the colony may attain a large size with a thin spreading irregular edge.

These old colonies sometimes show a certain degree of yellow pigmentation, but this is never the case in young cultures.

The consistency of the colony is creamy. Upon being disturbed with a needle it breaks down into milky fluid. In a very short time, however, for instance, in three or four days, the surface colonies become friable so that they break upon being disturbed or may even slide upon the surface of the medium.

As a general rule, homogeneous suspensions are easily made from young cultures of meningococci, but on the other hand, under some conditions of growth, this is not the case, and therefore a coccus which rapidly deposits from a suspension may nevertheless be a meningococcus.

(b) *On ordinary meat agar.* — The growth upon ordinary agar is very meagre, but later, after several subcultures upon agar, it may be more profuse. There is a tendency for the colonies to vary much in size, but this tendency disappears when the growth becomes vigorous.

(c) *In meat broth.* — The meningococcus will usually but not invariably grow in broth. More often the growth develops as a deposit upon the bottom of the tube, but upon shaking it may remain diffused through the medium. There is often a pellicle upon the surface. In peptone water there is no growth.

4. *Resistance to Deleterious Influences.*

(a) *Drying.* — As shown by Vines (Medical Research Committee Spec. Rep. Series, No. 2, p. 13) drying has a deleterious effect upon the vitality of the meningococcus. We look upon this factor as one of the most important in the growth of this organism.

The following experiment shows that two hours is sufficient to destroy the meningococcus when it is exposed to an ordinary degree of dryness.

Experiment. — Very small tufts of non-absorbent cotton wool mounted on wires were dipped into a thick suspension of meningococci, and then placed into test tubes plugged with wool. These were incubated at 37° C. and at different times one was removed and inoculated onto H5 serum agar.

10.30 a.m.	Start.	
11.15 a.m.	No. 1 removed.	Good growth.
11.30 a.m.	No. 2 removed.	Good growth.
12.30 p.m.	No. 3 removed.	No growth.
1.0 p.m.	No. 4 removed.	No growth.

Under the conditions of the experiment the wool would not be dry for some considerable time, and therefore we may assume that the meningococcus succumbs to drying almost immediately. This phenomenon is of great practical importance: all cultures should be "capped" as a routine, the growth being thus rendered more luxuriant. "Capping" also lengthens the life of a culture by several days, but even this is insufficient to protect stock cultures. These should always be "stabbed," and this alone will prolong life to several weeks.

The susceptibility of the meningococcus to drying also, of course, shows that throat swabs must be inoculated on to the culture medium immediately.

(*b*) *Viability in Culture.* It is well known that meningococci tend to die out in surface culture rapidly and suddenly. Upon ordinary Hb. serum agar slopes they cannot be relied upon to live more than three or four days. It is, however, found that stab cultures in the same medium will support life for weeks, and that liquid cultures are also long lived. The following table (Table 1) shows the viability in Hb. serum agar of a random collection of meningococci from the cerebro-spinal fluid. Occasional subcultures were taken from the stock culture over a period of two and a half to three and a half months, and in every case the cocci were found to be still alive.

The tubes must, of course, be capped with rubber and maintained in the incubator.

TABLE 1.

Showing the Length of Life of the Meningococcus in Hb. serum agar.

No. of Strain from the cerebro-spinal fluid	Date of Inoculation of tube.	Date of last Observation	Length of Time present Alive (weeks)
845	14/IV/17	29/VI/17	12
848	12/IV/17	"	12
841	21/IV/17	"	10
838	26/IV/17	"	10
527	8/III/17	"	16
536	5/III/17	"	17
619			17
632	11/III/17		16
687	24/III/17		14
686	10/III/17	"	16
567	5/III/17	22/V/17	11
737	29/III/17	29/VI/17	13
769			13
568	11/IV/17		12
705	10/III/17	22/V/17	10

It thus appears that stab cultures can be relied upon to live at least two to three months. There is no necessity to use the various elaborate media which have been brought forward for prolonging life in stock culture.

(c) *Cold.*—It is often stated that material from which the meningococcus is to be grown must be protected from cold in order to ensure a positive result.

We have not found this to be so, either in practice or in experiment.

Experiment.—Six Hb serum agar slopes were inoculated with meningococci, capped and placed into the ice chest at 7° C. They were then removed at different times and incubated:

10 a.m.	Start			
11 a.m.	1st tube incubated	=	Growth copious.	
12 noon	2nd ,,	,,	,,	,,
1 p.m.	3rd ,,	,,	,,	,,
3 p.m.	4th ,,	,,	,,	,,
5 p.m.	5th ,,	,,	=	,,
7 p.m.	6th ,,	,,	,,	,,

Nine hours in the cold had therefore no influence upon the vitality of the meningococci.

Primary nasopharyngeal cultures have often been noticed to survive twenty-four hours at room temperature, and to grow on sub-culture. Attempts to preserve stock cultures at 22° C., however, failed. The cultures were found to have died out after five days.

5. *Agglutination.*

Agglutinating sera may be prepared which have a specific action upon the meningococcus up to dilutions seldom exceeding 1 in 1,600. The ordinary titre obtained is commonly 1 in 400 to 1 in 800.

These sera appear to be quite specific in a dilution as low as 1 in 100 or even lower.

(a) *The division of meningococci into groups by agglutination.*—Upon the first introduction of these tests it was found that great variation in reaction existed between different strains isolated from the cerebro-spinal fluid, and thus agglutination came to be looked upon in some quarters as an inconstant phenomenon, so far as the meningococcus was concerned.

The first definite demonstration that this variation in reaction was due to actual differences in the strains of meningococci was made by Dopter.[1] He showed that certain inagglutinable strains originally isolated from the nasopharynx but later found in typical examples of cerebro-spinal fever, were capable of producing a specific agglutinating serum of their own. These

[1] She found that certain strains of meningococci, agglutinable by serum of a homologous

strains he named "parameningococci," in contra-distinction to the ordinary varieties agglutinable with meningococcus serum.

Dopter and his co-workers then showed that there were varieties even among "parameningococci" demonstrable by agglutination, and these were named "*Parameningococcus* α, β and γ."

Gordon and Murray carried out a systematic examination of a number of cerebro-spinal fluid meningococci, and by preparing monovalent sera from some of these strains were able to show that all were agglutinable by one or two of four monovalent sera. By absorption of agglutinin tests they then demonstrated that when a coccus is agglutinated by two sera one of these reactions is due to group action in the serum, and thus all cocci dealt with really fell into one of four relatively sharply demarcated, but related, groups, namely, I, II, III and IV.

Gordon and his associates have since had the opportunity of examining a large number of cases, and practically all of these have been shown to conform to this classification into four types. Many of these cases have been proved, by Tulloch, by means of absorption of agglutinin tests, and only three strains in 107 could not be placed in one of the four groups. The majority of strains belonged to Type I and Type II.

Griffith and Scott have examined a number of strains of meningococci, and have been able to divide them into groups according to their serological reactions. They, however, can only distinguish two main groups, which are not sharply defined as maintained by Gordon, but are linked together by intermediate and indefinite varieties.

Arkwright also has been able to divide a number of cerebro-spinal fluid strains into two main groups, linked together by a few intermediate strains. One group he considers to correspond mainly to "meningococci," while the other group consists mainly of "parameningococci." Similarly, Ellis has demonstrated two groups among the cases examined by him. His groups are, however, sharply defined, and all of his forty-six strains fell into one or the other. His Group II corresponded with the "parameningococcus."

It would appear that all investigators agree that there is serological evidence of two main groups of meningococci, while most associate these with the meningococcus and parameningococcus. This classification is generally considered to be more or less artificial. The groups are not sharply divided, and numerous intermediate strains are found. Gordon, on the other hand, holds that the two main groups (Types I and II) are sharply defined, while the intermediate types are also members of well defined sub groups (Types III and IV). He is of opinion that practically all meningococci obtained from the cerebro-spinal fluid in this country can be classified into one of his four groups, and therefore the vast majority of cocci which cannot

be so classified are *not* meningococci in the sense that they are *not* capable of producing cerebro-spinal fever.

Gordon's work leads to important conclusions with regard to the identification of doubtful cocci in the throats of contacts and indeed sets up a hard and fast diagnostic standard for the meningococcus—an organism which formerly was particularly indeterminate in specific reactions. We, therefore, have applied his standards to all of our strains with methods and materials of our own, with a view to confirmation or otherwise. We are indebted to Colonel Gordon for the original samples of serum by means of which our own cocci were first identified, but otherwise our work has been quite independent of his.

(b) Grouping cerebro-spinal fluid strains into "types".—In Table 2 is seen the result of carrying out quantitative agglutinations of each strain with monovalent sera corresponding to Gordon's Types, I, II, III and IV.

The origin of the sera used in this test was as follows:—

Type I.—No. 166. Titre 1 in 800.
Type II.—No. 414. Titre 1 in 400.
Type III.—No. 142. Titre 1 in 400–800.
Type IV.—No. 285. Titre 1 in 400–800.

Forty six strains were examined, and these represent the whole of the strains isolated by us without exception. Of these, twenty four were agglutinated with Type I serum, and twenty two were not, in a dilution of 1 in 100. Six of these latter agglutinated with Type IV serum and sixteen did not. None of the strains which agglutinated with one of these sera agglutinated with the other.

TABLE 2.

Classification of Meningococci by Agglutination.

Suspension of Pneumococcus in cerebro-spinal fluid. No. of Case.	Agglutinating Sera. Type I. 1 in 100	1 in 200	1 in 400	Type II. 1 in 100	1 in 200	1 in 400	Type III. 1 in 100	1 in 200	1 in 400	Type IV. 1 in 100	1 in 200	1 in 400
4	+	+	+	0	0	0	+	0	0	+	+	0
6	+	+	+	+	0	0	+	+	+	+	0	+
5	+	+	+	+	0	0	+	0	+	0	0	0
8	+	+	+	0	0	0	+	0	0	0	0	0
9	+	+	+	+	0	+	+	0	+	+	0	+
343	+	+	+	+	0	0	+	0	0	0	0	0
186	+	+	+	+	0	+	+	0	0	+	0	+
184	+	+	+	0	0	0	+	+	0	0	0	0
147	+	+	+	0	0	0	+	0	0	0	0	0
169	+	+	+	+	0	0	+	0	0	0	0	0
527	+	+	+	0	0	0	+	0	0	0	0	0
546	+	+	+	+	0	0	+	0	0	0	0	0
566	+	+	0	0	0	0	+	0	0	0	0	0
585	+	+	0	+	0	0	+	0	0	0	0	0
633	+	+	+	+	0	+	+	+	+	+	0	...

TABLE 2—*continued.*

Suspensions of cocci from cerebro-spinal fluid. No. of Case.	Agglutinating Sera. Type I. 1 in 100	200	400	Type II. 1 in 100	200	400	Type III. 1 in 100	200	400	Type IV. 1 in 100	200	400
687	+	+	+	0	0	0	-	0	0	0	0	0
696	+	+	-	0	0	0	-	0	0	0	0	0
705	+	-	0	0	0	0	-	0	0	0	0	0
769		+	±	±	0	0	-	0	0	0	0	0
846		+	+	-	0	0	±	0	0	0	0	0
868	-	+	+	0	0	0	-	0	0	0	0	0
1,028	+	+	...	...	0	...	...	0	...	...	0	...
809	+	+	±	0	0	0	±	0	0	0	0	0
1,068		±	0	0	0	0	0	0	0	0	0	0
286	0	0	0	+	+	+	+	0	0	0	0	0
344	0	0	0	+	±	-	0	0	0	0	0	0
414	...	0	...	+	±	-	...	0	...	0	0	0
468	0	0	0	-	-	0	0	0	0	0	0	0
568	0	0	0	±	±	0	-	0	0	0	0	0
632	0	0	0	+	±	-	0	0	0	0	0	0
704	0	0	0	+	-	0	0	0	0	0	0	0
790	0	0	0	-	-	0	0	0	0	0	0	0
737	0	0	0	+	-	0	0	0	0	0	0	0
845	0	0	0	-	+	0	+	0	0	0	0	0
841	0	0	...	±	-	...	0	0	...	0	0	...
1	...	0	0	...	0	0	...	+	0	...	0	0
142	0	0	0	-	0	0	-	-	+	0	0	0
206	0	0	0	...	0	...	-	0	0	...	0	...
1,118	0	0	0	-	0	0	-	-	+	0	0	0
695	0	0	0	0	0	0	+	0	0	0	0	0
285	...	0	...	...	0	...	...	0	...	+	-	-
357	0	0	0	+	-	0	0	0	0	+	-	0
415	0	0	0	-	-	0	0	0	0	-	-	0
567	0	0	0	+	-	0	0	0	0	+	-	-
619	0	0	0	+	-	-	0	0	0	+	-	-
949	0	0	0	-	-	-	-	0	0	-	-	-

Throughout this paper—

+ = complete agglutination.
± = partial agglutination.
0 = no agglutination

With these two sera, therefore, 30 of the 46 strains were clearly accounted for in Gordon's scheme. When the remaining 16 strains were tested, 11 were found to agglutinate only or chiefly with Type II serum, while 5 strains were found to agglutinate only or chiefly with Type III serum.

Thus all of our cerebro-spinal strains reacted to one or more of Gordon's four "type" sera, and none were found to fail to agglutinate.

A study of the table will show that the type classification indicated rests largely upon a quantitative basis and that there is evidence of close relationship between groups. Thus, Type I cocci are constantly agglutinated by Type III serum up to 1 in 100. Some of these cocci are also slightly affected by Type II serum. Type IV cocci are constantly agglutinated by Type II serum often as high as 1 in 200. Types II and III cocci are not affected by the other two sera.

From these results it would appear that Type III is a coccus which produces a serum capable of agglutinating itself and Type I, and that Type II serum is capable of agglutinating Types II and IV. Types I and IV sera are more "specific," and contain less group agglutinins, since they have no effect upon the other types. Thus in general it may be said that there is evidence of close relationship between Types I and III and between Types II and IV, and further, that Types I and IV are the more highly specialised members of each pair. If Types I and III are looked upon as Group A and Types IV and II as Group B, the two groups will be seen to be quite sharply divided, although of course related, and these may be indeed the two groups or types referred to by other authors.

Gordon, however, goes further than other authors and claims that each of his four types are distinct, although it may be inferred from the group agglutinins that they are related. This claim he supports by subjecting the strains to absorption of agglutinin tests, when he finds that each strain absorbs agglutinins for one only of his four types, and thus, whatever inferences may be drawn from the presence of group affinities, every strain found in the cerebro-spinal fluid in these cases really belongs to one only of four relatively distinct groups.

We have also subjected all our available strains to absorption tests.

(b) Grouping into "types" by absorption of agglutinin tests.—In the following table (3) are given the results of absorbing each of the four "type" sera with the same series of meningococci as were included in the agglutination table. The agglutinating action of the absorbed serum upon "type" cocci is then compared with that of the unabsorbed, and the loss of agglutinating action in degree of absorption is indicated in the table by the number of *plus* signs.

The "type" cocci used in this experiment were as follows:—

Type I.—No. 626.
Type II.—No. 632.
Type III.—No. 1,118.
Type IV.—No. 619.

It will be noticed that they were in every case different strains from those used for the production of the serum. Throughout our work we have not maintained one particular culture as the standard "type." When we have required a further supply

of suspension we select any regularly agglutinating and absorbing strain from among our surviving "stocks," and use it as the standard for the time being.

It is seen that all cocci which agglutinated with Type I serum absorbed Type I agglutinins strongly. The agglutinins of other types, in particular of Type III, were not absorbed. A slight absorption of Type IV agglutinins by No. 705 may be disregarded.

The cocci which agglutinated with Type II serum, and not with Type IV, absorbed Type II agglutinins only. Unfortunately, we were unable to test all of our few examples of Type III cocci. Of the three examined, two absorbed Type III agglutinins only and one absorbed no agglutinins.

TABLE 3.

Classification of Meningococci by Absorption.

Suspensions of cocci from cerebro-spinal fluid. No. of Case.	Degree of absorption of agglutinins of the four types.																							
	Type I.									Type II.			Type III.			Type IV.								
4	+	+								0			0			0								
6		+								0			0			0								
5	+	+								0			0			0								
8										0			0			0								
9										...			...			...								
343										0			0			0								
186										0			0			0								
192					+					0			0			0								
437		+								0			0			0								
469		+								0			0			0								
527										0			0			0								
536		+								0			0			0								
586		+								0			0			0								
565		+								0			0			0								
633										0			0			0								
687			+							0			0			0								
686										0			0			0								
705	+									0			0			.								
769	+		+							0			0			0								
846										0			0			0								
868										0			0			0								
1028										0			0			0								
809										0			0			0								
1088										0			0			0								
286			0										0			0								
344			0										0			0								
414			0										0			0								
468			0										0			0								
568			0										0			0								
632			0										0			0								
701			0										0			0								
790			0										0			0								

TABLE 3 [illegible]

[illegible]	[illegible]			
[illegible]	Type I	Type II	Type III	Type IV
737	0	[illegible]	0	0
845	0	[illegible]	0	0
841	0	[illegible]	0	0
1	[illegible]	[illegible]	[illegible]	[illegible]
142	0	0	[illegible]	0
206	[illegible]	[illegible]	[illegible]	[illegible]
1,118	0	0	[illegible]	0
695	0	0	[illegible]	0
285	0	0	[illegible]	[illegible]
357	0	0	0	[illegible]
415	0	0	0	[illegible]
567	0	0	0	[illegible]
619	0	0	0	[illegible]
989	0	0	0	[illegible]

For technique cf. p. 82. In this table an absorption [illegible] means that the titre of the standard serum was reduced to one half as the result of absorption [illegible] reduction to one quarter [illegible] reduction to one-eighth. This was usually the limit of observation.

The cocci which agglutinated with Type IV serum all absorbed Type IV agglutinins fairly strongly.

Thus each, except one, of our strains of meningococci when tested by the absorption of agglutinin method fell into one only of the four groups of Gordon. These groups were sharply defined, and no coccus, or perhaps only one, showed any tendency to lie in an intermediate position between any two of the four types.

Certain investigations have been carried out with the view of determining the nature of the outstanding coccus, No. 695.

No. 695 was a fatal case of cerebro-spinal fever. The cerebro-spinal fluid contained pus and typical meningococci. These latter were isolated upon our Hb. serum agar in the ordinary way, and when tested were found to agglutinate completely with Type III serum and Flexner's polyvalent serum in a dilution of 1 in 200 at least. About fourteen days later subcultures were made from the stock stab culture, and this was then found to be contaminated with a long chained streptococcus. No streptococci were observed in the original films. The culture was purified, and a stock of carbolised suspension was made up. Owing to an accident the stock culture was now lost. When agglutinations were next carried out with the suspension, the coccus was found to be inagglutinable with the four "type"

sera (1 in 200), but still agglutinable with Flexner's serum 1 in 200 and partially 1 in 400. No absorption of agglutinin from the four "type" sera could be demonstrated on repeated tests. The unknown coccus absorbed its own agglutinins only from Flexner's serum. In order to throw more light upon this coccus, its agglutinogenic action was tested by preparing a rabbit by intravenous injection. A serum was thus obtained which was capable of agglutinating No. 695 and Type III cocci, and also to a slightly less extent Type I cocci. A feeble action was observable upon Type II cocci, and none upon Type IV cocci.

This No. 695 serum was then saturated in different samples with No. 695 coccus and each of the four "type" cocci, and these saturated samples were compared with an unsaturated sample as regards the actions upon No. 695 coccus and the "type" cocci.

The results of these experiments were as follows :-

Saturation with Type I cocci removed agglutinins for Type I completely, and slightly for Type III and No. 695.

Saturation with Type II cocci removed agglutinins for Type II.

Saturation with Type III cocci removed agglutinins for Type III completely, and slightly for Type I and No. 695.

Saturation with Type IV cocci removed agglutinins for none.

Saturation with No. 695 cocci removed agglutinins for No. 695 and Type I completely. Type III was unaffected.

On the whole, therefore, it would appear to be clear that No. 695 is a variant from the Type I III group. From its agglutinations, and also its agglutinogenic action, it would seem to be more closely related to Type III, but its absorptive action from its own serum is more suggestive of a relationship to Type I.

From these results, detailed above, we feel that we are justified in supporting Gordon's claim that practically all meningococci which have been found to be capable of producing cerebro-spinal fever can be demonstrated to belong to one of his four groups.

This being so, it must follow that practically all cocci which cannot be shown to fall into one of his four groups are incapable of producing cerebro-spinal fever, and therefore Gordon's types assume great importance in practical diagnosis.

In reading a statement of this character, however, caution is necessary. In some cases, owing to a temporary inagglutinability, the proof of the "type" of a coccus may be difficult and require absorption tests. In routine practice these tests could seldom be applied, and therefore it will sometimes occur that a real meningococcus is not proved to be a Gordon type

and is thus discarded as of no importance. Such methods as this are inevitable under the pressure of work, but they are not so serious as to invalidate the system, neither do they materially detract from the importance of Gordon's findings.

For general epidemiological purposes we do not ourselves look upon the pathogenic meningococ as consisting of four types but rather of two groups, each group consisting of two types, namely, Types I and III constituting Group I and Types IV and II constituting Group II. The relationships disclosed by the agglutination tests warrant this grouping, and its correctness is supported by a number of other observations to be detailed later. It appears to be tolerably certain that these two groups correspond to the "meningococci" and "parameningococci" of other authors.

Note.—After the completion of this report we received a copy of No. 114 of the Reports to the Local Government Board upon Public Health and Medical Subjects, by Eastwood, Gordon, Scott and others. We regret that we are unable to refer to the paper in greater detail, since many of the findings appear to be in accord with our own. In their report these gentlemen advocate that even plan the grouping of meningococci by mechanical methods is an artificial procedure which depends upon the arbitrary selection of particular strains as standards. They state that a classification based upon certain representative "types" will not necessarily hold if other samples of the same "types" are selected as standard, and that different laboratories may find themselves in the possession of standards which do not correspond.

So far as we (personally) are concerned we are prepared to admit that there is some possibility of atypical members of certain types, as selected to represent "standards." We do not, however, consider that the similarity between the I-III group and the IV-II group is close enough to allow of much chance of confusion of standards, but undoubtedly Types IV and II have sometimes been rejected in routine, especially when isolated from the throat, and in these cases the presence of strains which have the characters of such type cannot be denied now and in past years. If, on the other hand, strains are selected as representing what are "typical," and not the characters of a "type" in a generalizing sense, it appears to us that the differences are not sufficiently great to avoid confusion.

The fact that strains exist which exhibit the features of two types to a variable degree does not, in our opinion, invalidate a classification based upon the general characters of the types.

Our attitude in the matter is therefore as follows:

We believe that two main groups of meningococci exist, viz., that each group contains a number of strains possessing the same characters. It appears to be a matter of choice as to whether we call each of these groups a condition or possibility and those strains which we regard as "types" a classification based upon these "types" will be relatively sharp. The main differences in such strains are sufficiently distinct to allow a certain degree of sophistication of "types" but even if this is not so, the epidemiological information obtainable from an arbitrary classification is of value and warrants its retention.

Our opinion is further borne out by the fact that

(1) Variations in the agglutinability of meningococci. When compared with the ease with which such bacteria as *B. typhosus*

lend themselves to agglutination, it must be allowed that the meningococcus is much more capricious.

This irregularity of behaviour is confined almost entirely according to our observations to Types II and III, which we have described as sub-types of Groups II and I.

One of the most noticeable features is the frequent *inagglutinability* of these cocci upon first isolation from the cerebro spinal fluid (dilution of serum, 1 in 200). Among our Type I strains we had no examples of this phenomenon, while one Type IV case (No. 619) failed at first to agglutinate with Flexner's polyvalent serum, although the "type" serum reacted normally.

Among the Type III cocci No. 206 failed to agglutinate entirely at first with any serum, while No. 1 agglutinated with Flexner serum and not with the type serum.

Type II furnishes most examples of inagglutinability :—

No. 286.—At first nil, later Type II and Flexner.

No. 568.—At first nil, later Type II and Flexner.

No. 632.—At first nil, later Type II and Flexner.

No. 737.—At first nil (slight II), later Type II and Flexner.

No. 414.—At first Flexner, later Type II and Flexner.

No. 704.—At first Flexner (slight II), later Type II and Flexner.

No. 168.—At first slight Flexner and II, later Type II and Flexner.

This inagglutinability does not depend upon feebleness of growth, since care was taken to avoid this error, but feebleness is undoubtedly responsible for the temporary losses of agglutinability observed in stock cultures.

There is no doubt that, apart from recent isolation there is a difference in the agglutinability of the various types, and in this matter again we have found Types II and III to be mostly at fault.

Type II appears to us to be always more difficult to agglutinate than the others. This may of course be a question of its value as an antigen, since we have not obtained a serum which agglutinates Type II higher than 1 in 400, while the other types commonly reach 1 in 800 or more.

We have required to prepare two rabbits only with Type I cocci (No. 166), and both attained a titre 1 in 800. Four rabbits have been injected with Type II. Two animals with No. 344 reached 1 in 400, and one with No. 414 also reached 1 in 400, while another only reached 1 in 200. Two animals were injected with No. 142 (Type III), and one reached 1 in 800 and the other 1 in 400. A third animal injected with a Type III strain

("Chaco") kindly supplied to us by Col. M. H. Gordon, reached 1 in 800. Only two animals were treated with Type IV (No. 285 and Nos. 285 and 619 mixed), and both reached 1 in 800.

It is thus seen that there is a tendency for Type II sera to be lower in titre than the others.

On the other hand there is considerable variation in the agglutinability of the different Type II cocci themselves as is seen in the accompanying table, which shows a number of Type II cocci acted on by one serum.

TABLE 5.

Variety in the Agglutinability of Type II Strains.

Strain No.	Serum No. 414			
	1 in 100	1 in 200	1 in 400	1 in 800
286	+	+	+	0
344	+	+	+	+
414	+	+	+	0
468	+	+	0	0
568	+	+	0	0
632	+	+	0	0
704	0	0	0	0
737	+	+	+	0
780	+	+	0	0

+ = complete agglutination.

0 = no complete agglutination.

NOTE.—Of the other cocci Nos. 704 agglutinated best.

It may therefore be said that the agglutination of Type II cocci, in particular, is somewhat capricious upon first isolation from the cerebro-spinal fluid, but that this characteristic is very largely lost after one or two subcultures.

6. *Fermentation Tests.*

Fermentation tests were carried out on eighteen unselected strains of meningococci from the cerebro-spinal fluid.

For this purpose we at first used ordinary serum agar containing the test sugar and litmus, but upon this medium the results were very inconstant and the rapid production of alkali often masked the acid formed by the sugar fermentation. We later tested the strains upon a peptone water medium containing 1 per cent. of serum, and upon this the results were more constant and sharp.

Our test sugars were glucose, maltose and saccharose (C. M. S.).

TABLE 6.

Fermentation Reactions of Cerebro-Spinal Fluid Strains.

No. of Strain	1 Day.			2 Days.			3 Days.			4 Days.		
	G.	M.	S.	G.	M.	S.	G.	M.	S.	G.	M.	S.
588	0	+	0	+	+	0	+	+	0	+	+	0
619	0	+	0	+	+	0	+	+	0	+	+	0
696	0	+	0	+	+	0	-	+	0	+	+	0
527	0	0	0	0	+	0	-	+	0	+	+	0
687	0	+	0	0	+	0	-	-	0	+	-	0
567	0	+	0	+	+	0	-	+	0	+	+	0
845	0	+	0	+	+	0	+	+	0	+	+	0
1,118	0	+	0	-	+	0	-	+	0	+	+	0
769	0	+	0	+	+	0	-	+	0	+	+	0
705	0	+	0	0	+	0	+	+	0	+	+	0
809	0	+	0	+	+	0	-	+	0	...	...	...
737	0	+	0	-	+	0	...	...	...	...	...	...
1,028	0	+	0	+	+	0	...	...	...	...	...	...
841	0	+	0	-	+	0	...	...	...	...	...	...
632	0	0	0	0	+	0	+	-	0	+	-	0
868	0	+	0	+	+	0	+	+	0	+	+	0
536	0	+	0	-	+	0	-	+	0	+	+	0
949	0	+	0	-	-	0	-	-	0	...	...	...

It will be observed that all of these strains fermented glucose and maltose, but not saccharose.

We have been unable to confirm the statement of W. M. Scott (Reports to the Local Government Board on Public Health and Medical Subjects, N.S. No. 101, 1916, p. 59) that meningococci may be roughly divided into two groups, one of which usually ferments maltose before glucose and the other glucose before maltose. As is seen above, all of our strains fermented maltose before glucose. On further analysis of our table, however, there is some indication of a subdivision depending upon the fermentation of glucose.

Scott's "glucose preferring strains" mostly belong to what he describes as his "Clayton" group, and this group almost certainly corresponds imperfectly to our Group II.

If, now, the cases tested above are divided up into two groups, Types I and III, and IV and II, and then the degree of fermentation of glucose noted on the second day's growth, the following result is obtained

TABLE 7.

Fermentation of Glucose by Groups I and II Strains.

Strain No.	Type.	Degree of Fermentation of Glucose.
686	I	—
527	I	o
687	I	o
1,118	III	—
766	I	—
705	I	o
869	I	—
1,028	I	—
888	I	—
586	I	—
588	II	—
619	IV	—
567	IV	—
845	II	—
737	II	—
841	II	—
642	II	o
949	IV	—

It is thus seen that Group II (Types IV and II) ferments glucose in the majority of cases more strongly than Group I, and, on these grounds, this Group II may be described as "glucose preferring."

The reaction has little practical importance, but it affords further evidence of the correctness of the subdivision of meningococci into two main groups and two sub-groups.

III.—CASES OF CEREBRO-SPINAL FEVER.

1. *The Bacteriological Diagnosis of Cerebro-Spinal Fever.*

The only satisfactory direct method of diagnosing cerebro-spinal fever bacteriologically is by the demonstration of meningococci in the cerebro-spinal fluid. The suggestion has been made, however, that in cases where this method fails the patient's serum may show positive agglutination to stock suspensions of meningococci and, further, that suspicious cases may be proved by growing the cocci from the nasopharynx.

(a) *The examination of the cerebro-spinal fluid.*—The physical appearance of the cerebro-spinal fluid from a case of cerebro-spinal fever is very variable. Sometimes it may almost appear like pus, while in other cases there may be no detectable opacity.

A specimen should always be centrifuged and the deposit stained by Gram and also by carbol thionin. Meningococci may be found by this latter method when not discoverable by Gram.

the staining being much more intense. The thionin film is first examined, and if meningococci are found the staining reaction is confirmed by examination of the Gram film. It is often necessary to search for a considerable time before any cocci are found. They are mostly extra-cellular, sparsely scattered through the film, but sometimes of course they may have the appearance of Gonococci.

The discovery of Gram negative diplococci in a film is for practical purposes sufficiently diagnostic of cerebro-spinal fever, in spite of the fact that other gram negative cocci have been said to cause meningitis. In all our cases, however, we have resorted to confirmation by culture, and in every instance in which we have found meningococci in the film we succeeded in isolating the strain. Sometimes a case has been met with in which the meningococcus has been isolated on culture from a perfectly clear fluid, containing a very slight excess of cells and no visible meningococci.

No. 841.—A perfectly clear fluid containing only 32 polymorphs and 6 lymphocytes per c.mm.; no cocci seen in films. Culture on Hb. serum agar produced one or two colonies of meningococci, which proved to be Type II by agglutination tests.

When the cerebro-spinal fluid is clear it is necessary to establish the presence of a meningitis, before discarding the case as negative, by an accurate cell count.

During the past season we have examined 49 cases of cerebro-spinal fever, and meningococci were isolated in 46 cases.

The details of the negative cases are as follows:

(1) No. 436. Cerebro-spinal fluid opalescent, containing polymorphonuclear and endothelial cells. No certain meningococci were seen, but possibly one. Cultures remained sterile.

(2) No. 978. Cerebro-spinal fluid clear, but contained a few polymorphonuclear cells. No meningococci were seen. Cultures remained sterile.

(3) No. 847. Cerebro-spinal fluid thick. Polymorphonuclear and endothelial cells. No meningococci seen. Cultures remained sterile.

The clinical condition of these men was suggestive of cerebro-spinal fever, and the state of the cerebro-spinal fluid was consistent with this disease. Therefore, although not proved, they may be accepted as cases. It is thus seen that meningococci are capable of being grown from the great majority of these cases, since in only 3 instances in 49 did we fail.

(b) *Examination of the patient's serum for agglutinins.*—It has been suggested that the serum of a patient suffering from cerebro-spinal fever may be tested for agglutinins against the meningococcus, but it is doubtful whether this method of diagnosis has received any extensive confirmation.

Flack (Medical Research Committee Spec. Rep. Series No. 3, p. 41) records that he has tested three cases (no meningococci found in the cerebro-spinal fluid) and obtained specific agglutination by the ordinary macroscopic method up to a dilution of 1 in 40 to 1 in 100 between the fifth and tenth day after the onset of the disease. We have tested the method in twelve cases as follows, using a standard suspension of meningococci of the same type as that infecting the case :—

TABLE 8.

Agglutinating action of Patient's Serum.

No. of Case	Type.	Result with the following dilutions of patient's serum		Days after onset of illness
		1 in 25	1 in 50	
5,86	I	0	0	5
632	II	0	0	5
566	I	Trace	0	7
568	II	0	0	7
414	II	0	0	8
567	IV	0	0	7
415	IV	0	0	8
633	I	Trace	0	6
565	I	0	0	11
737	II	0	0	5
705	I	0	0	4
619	IV	0	0	11
Control	—	0	0	

From these results we must conclude that this method of diagnosis is valueless.

(c) *The examination of the patient's nasopharynx for meningococci.*—Flack (Medical Research Committee Spec. Rep. Series, No. 3, p. 41) has stated that all cases of cerebro-spinal fever have meningococci in the throat in the earliest stages of the disease. Actually excluding those of his cases in which no meningococci were grown from the cerebro-spinal fluid, it is seen that thirty-one cases of the disease had meningococci in the throat invariably, although on one occasion the meningococcus of the throat was of a different type to that of the cerebro-spinal fluid.

He therefore concludes that "in cases in which the cerebro-spinal fluid is at first indeterminate microscopically or from which a growth of the meningococcus is not obtained, a growth of the meningococcus from the nasopharynx is exceedingly helpful in making a diagnosis." In other words, the cases of meningitis of uncertain origin are diagnosed as meningococcal if meningococci are isolated from the throat.

We ourselves are unable to confirm Flack's results as to the constant presence of meningococci in the throat, because our swabs were taken on the average nine days after onset, while Flack took his much earlier.

Rather less than half of our thirty-four cases showed meningococci in the throat.

On general grounds, however, it would appear very probable that meningococci are constantly present in the throat as stated by Flack; nevertheless, we doubt whether this fact can be taken as being practically diagnostic in certain cases. We have found on three occasions during the past year that between 6 and 7 per cent. of normal persons carried meningococci in the throat, and this proportion is sufficiently high to vitiate an indirect diagnosis of this sort.

An element of doubt as to the correctness of the diagnosis must always exist, and this is undesirable in the Navy where a positive diagnosis may affect the movements of hundreds of men.

It will be observed that in Flack's series of fifty-nine cases diagnosed as cerebro-spinal fever, no meningococci were isolated from the cerebro spinal fluid in nineteen, while in our series of forty-nine cases we failed to grow the cocci on three occasions only.

2. *Number and Bacteriological Type.*

Forty-six cases of cerebro-spinal fever, proved by isolation of the meningococcus from the cerebro-spinal fluid, have been observed during the past season. Three further cases in which no meningococci were found were considered to be cerebro-spinal fever on clinical grounds.

The incidence of the different types was as follows:—

Type	I.—	24 cases.
,,	II.—	11 ,,
,,	III—	4 ,,
,,	I-III.—	1 ,,
,,	IV.—	6 ,,

It is thus seen that Type I predominated considerably. If the related types are taken together, namely, Types I–III (29 cases) and Types IV–II (17 cases) it is clear that the "meningococcus" in this outbreak was almost twice as common as the "parameningococcus."

3. *Distribution.*

The following is the distribution of the forty-six cases of cerebro-spinal meningitis with positive cerebro-spinal fluid:—

TABLE 9.

Distribution of Cases of Cerebro-Spinal Fever.

R.N. Barracks, Portsmouth	32 cases.		
A Block	Room A, 1 case	Room AA, 1 case	
B ,,	B, 0 ,,	BB, 1 ,,	
C ,,	C, 0 ,,	CC, 1 ,,	
D ,,	D, 1 ,,	DD, 2 cases	
E ,,	E, 1 ,,	EE, 0 case	
F ,,	F, 1 ,,	FF, 1 ,,	
G ,,	G, 7 cases	GG, 8 cases	
H ,,	H, 1 case	HH, 3 ,,	
M ,,	M, 0 ,,	MM, 1 case	
W.R.B.	1 ,,		
?	1		
"Overflow Ships" R.N. Barracks			
H.M.S. "B	1 case		
,, "F	2 cases		
,, "S"	1 case		
,, "W" ...	1		
Forton Barracks, R.M.L.I.	1		
Eastney Barracks, R.M.A.	4 cases		
R.N. Camp	3 ,,		
R.N. Air Station... ...	1 case		

In order to compare the "rate" of disease in these various establishments it is necessary to know roughly the population. The following figures represent the *sleeping capacity*, not, of course, the totals on the books of the various establishments:—

Population of "overflow ships" represented by	1	
,, R.N. Barracks	,,	50
,, R.N. Camp	,,	1
,, Forton Barracks	,,	1/2
,, Eastney Barracks	,,	1/3

It is now noticeable that, although the sleeping accommodation of the Royal Naval Barracks was only three times as great as that of the "overflow" ships, the actual cases of cerebro-spinal fever were six times as numerous.

Further, the sleeping accommodation of G Block is 1/7, and yet no less than fifteen cases occurred in this one block. If this block is omitted from the figures for the Barracks, the incidence of the disease in this establishment is then found to be practically the same as in the "overflow ships."

The special susceptibility of the Royal Naval Barracks is due therefore to the presence of G Block, and this building does not differ in any way from the others except in its population. "New entries" are messed in this block.

These figures also make it clear that there is no reason to fear the outbreak of an epidemic in a ship, even an old ship, any more than in a hygienic shore establishment.

The incidence in one of the Marine establishments was greater than in the other, and always has been greater. There is, however, no obvious difference between these establishments other than the presence of recruits at Eastney.

The evidence brought forward in this section, therefore, indicates that the most important factor in the development of cerebro-spinal fever in the Navy at Portsmouth is the presence of "new entries" and "recruits," and not the differing conditions of hygiene in the various establishments.

The special susceptibility of "new entries" obviously leads to the question of age in the next section.

4. *The effect of Age and Length of Service.*

In the previous section it appears that the fact of "new entry" is most important in connection with the occurrence of cerebro-spinal fever, but to some extent, of course, "new entry" is synonymous with youth.

The following list shows the number of cases which occurred at different ages, and the number of these that were "new entries":—

Age.	No. of Cases.	No. of New Entries.
16	2	0
17	1	1
18	23	21
19	6	5
21	1	1
22	1	1
23	1	1
24	1	1
29	4	4
32	1	0
36	1	1
38	1	0
44	1	0
46	1	0
55	1	0
	46	36

This list shows the large number of "new entries" among the affected men. Under the term "new entry" are included only those men who have been in the service for a few days, or at most a few weeks. There are, of course, large numbers of men aged 18, 19 or 20 who entered the service several months before, but these are not included as "new entries," and among these only three cases of cerebro spinal fever occurred.

There is therefore reason to suppose that the factor of youth alone is not essential

Again, a considerable proportion of cases occurred among "new entries" who were not quite young, but whether this proportion is greater among elderly "new entries" than among elderly men who had been in the service for some little time it is impossible to say. We have no records of the ages of "new

entries" but it would be incorrect to imagine that they were all quite young. Most of these were young, but we have no reason to suppose that up to the age of 30 at least the average ages of the new entries differed markedly from that of the general population. Neither have we any reason to suppose that the average age of "new entries" differed very much from that of the majority of other men in the various establishments.

We therefore are of opinion that the fact of being a "new entry" is much more important in the causation of the disease than the fact of being young. How this factor operates it is difficult to suggest. Some of the men no doubt are brought from distant non populous parts of the country and are massed together with town dwellers infected with bacteria to which the former are not accustomed. Others again, are in poor physical condition, ill fed, and liable to infections when exposure is excessive.

5. *Seasonal Incidence.*

Chart No. 1 shows the number of cases of cerebro-spinal fever which occurred every week during the season. A similar curve for 1916 is superimposed.

The first case of the 1916-17 season was observed on October 28th, and the second on November 29th. From this time cases occurred practically every week, increasing in number to a climax about the end of February. After this date the number of cases rapidly declined to zero about the beginning of May, but a secondary small rise took place during the end of May and June. The last case of the season was admitted on June 24th.

It will be noticed that the milder outbreak of 1915-16 had a very similar seasonal course. It started over two months later, but the summit was only about a fortnight later than in 1916-17, while the ends coincide closely if we disregard the secondary rise in 1916-17. There is thus a well defined seasonal incidence among these cases so far as the height of the outbreak is concerned, but the start and the end of the outbreak may vary according to the annual severity.

In Chart 2 is depicted the seasonal incidence of the "types" comprising the outbreak of 1916-17.

It will be seen that the Type I-III group alone accounted for the whole of the cases at the beginning and the end of the outbreak, and further that they predominated throughout the course. The Type IV-II group merely broke out into a smaller number of cases when the epidemic was well established.

It would therefore appear that the Type I-III group (meningococcus) was of greater epidemic importance than the Type IV-II group (Parameningococcus).

6. *The presence of Meningococci in the Throats of Cases.*

(*a*) *After the onset of symptoms.* Thirty-four cases in our series bear upon this question. In accordance with the regulations these men, upon recovery, were swabbed once every fourteen days for six months, every opportunity was therefore present to disclose chronic carriers.

In 13 of these men no meningococci were found, while in 21 meningococci were present. On further examination, however, it is seen that 6 of these latter carried cocci differing from the infecting strain, and for the purposes of this comparison must be considered negative. Thus, rather more than half of the cases showed no meningococci on repeated examination.

This result is in general accord with those of previous workers, but it has been stated that if the examination is made in the early stages of the disease the meningococcus may be found practically always. From Flack's cases (Medical Research Committee Spec. Rep. Series, No. 3, pp. 42 3), excluding those in which no meningococci were found in the cerebro-spinal fluid, it is seen that 31 cases of the disease had meningococci in the throat, and 30 of these the same type of meningococcus. As a routine Flack swabbed his cases at the time of the lumbar puncture. Unfortunately we were unable to do this, and therefore we have analysed our material to determine the importance of this factor (Table 10).

The first swab was made on the average nine days after onset; in the negative cases, 11 days; and in the positive 8 days. This difference of three days signifies nothing, because the positive cases did not *prove* positive until nineteen days on the average. These figures therefore do not lend support to the view of the necessity of early swabbing.

On the other hand, there is some evidence that more positives are obtained on the first swab than on subsequent swabs, while 3 cases were positive on the first swab only.

TABLE 10.

The presence of Meningococci in the Throats of Cases.

No.	Type in cerebro-spinal fluid.	Type in throat.	How many times swabbed	Which Swabs Positive	First Swab (days after onset).	First Positive (days after onset)
1	I	I	7	1st	8	8
6	I	I [illegible] IV	24	1st [illegible] 3rd, 12th [illegible] 18th	6	6
8	I	—	16	0	16	—
142	III	—	8	0	20	—
200	I	—	7	0	5	—
182	I	—	10	0	6	—
208	III	II	11	1st, 6th, 7th, 9th, 8th	8	15

TABLE 10.—*continued.*

No.	Type of case (Clinical Group)	Result of Operation	Days after onset when first swab was taken	When Swabs Negative	Days Swabs taken after onset	Days Patient in Hospital after onset
457	IV	IV	4	8th	4	18
414	II	II	13	1st	9	9
415	IV	IV	22	2nd 3rd 4th 18th and 23rd	3	9
437	I	IV	2	1st	5	5
488	II	II	1	2nd	9	9
527	I	II	9	5th	19	48
536	I	IV	18	5th	15	54
566	I		9	6	11	
568	II	I	14	7th	14	102
567	IV		11	11	11	
585	I		11	6	14	
619	IV	IV	13	5th	21	57
633	I		11	6	11	
632	II	II	14	3rd 4th 8th and 10th	11	78
687	I		2	6	19	
705	I	I	15	9th 8th and 9th	2	33
769	I		18	6	4	
809	I	I	26	2nd	2	26
747	II	II	14	1st 2nd and 10th	6	6
848	II	II	15	7th	8	49
846	I		8	6	8	
841	II	II	14	1st, 5th and 6th	8	8
888	I	I	10	1st, 2nd and 4th	19	19
949	IV	IV	8	1st 8th and 7th	13	13
1 028	I		10	6	7	
1 088	I	IV	6	1st	10	10
1 118	III		8	6	8	

Analysis

34 cases: 15 negative to throat; 6 positive with different swabs } = 19 negative
18 positive = 15 positive

Average time after onset when 1st swab was made, 9 days.
Average time after onset when 1st swab was made in fatal cases, 11 days.
Average time after onset when 1st swab was made in positive cases, 8 days.
Average time after onset when positives were found positive, 19 days.
Of the positives:
8 were positive on 1st swab, 9 days (average) after onset.
2 were positive on 2nd swab 14 days (average) after onset.
2 were positive on 3rd swab 21 days (average) after onset.
1 was positive on 4th swab.
1 was positive on 8th swab.
1 was positive on 7th swab.

On general grounds it would appear highly probable that meningococci exist in the nasopharynx in the early stages of the disease almost invariably as stated by Flack, and from our results and those of others it is clear that in most cases the cocci rapidly disappear. This suggests a mild infection, and certainly in our positive cases the degree of growth was much inferior to that obtained from most carriers; indeed, only one or two colonies were usually detected. The average time during which our positive cases gave positive swabs was one and a half months, which is also the average period during which our ordinary carriers remained positive. It might, therefore, be thought that the "case" carriers were just as persistent as ordinary carriers. In reality there is a difference. The ordinary carriers were not examined after they had remained negative for three weeks, but *cases* were examined for six months and therefore there was a much greater chance of finding the cocci in the latter. If the *cases* are considered on the same basis as the carriers, the average carrying period is reduced to one month.

(b) Before the onset of symptoms.—We have had the unique experience of having tested 26 of our cases before the onset of the disease (Table 11). These tests were performed on each individual at an interval varying between two and seventy five days before the onset. The result was in every instance negative. One case was examined three times and one twice. This finding is important, because it indicates that the cases can seldom be carriers of meningococci before the onset, and the period of time intervening between the acquisition of the coccus and the onset of the disease must usually be short.

From our observations upon this matter we conclude that cerebro-spinal fever is not as Gordon (Medical Research Committee Spec. Rep. Series, No. 3, p. 19) states "an instance of a carrier developing the disease" but an instance of a non-carrier acquiring meningococci which rapidly spread beyond the confines of the nasopharynx and produce the disease.* No doubt meningococci may be cultivated from the nasopharynx at this stage constantly, but these rapidly disappear and very few individuals remain as persistent carriers after convalescence.

* [illegible] series, *Lancet*, 1917, II, 728 (that he did not use the term "carrier" in connection with reference to the state of the case before the onset, but to the state at the onset). Dr. Eastwood, however (Reports to the Local Government Board on Public Health and Medical Subjects, 1916, No. 111; 1917, p. 5), deliberately makes an assumption which has shown to be [illegible]

However, I believe general agreement on the following matters:

1. Cerebro-spinal fever develops in persons who prior to the onset of the disease have carried the meningococcus in their nasopharynx.

Dr. F. V. Anderson [illegible] a recent review that the presence of meningococci in the throat early in the disease suggests that every [illegible] spinal fever [illegible] a person who is normally a carrier (*Lancet*, 1917, II, 818).

TABLE II

State of the Throat of Cases before the onset of the Disease

No.	Date of Swab [illegible]	Result	Date of Onset	[illegible]
68	1st Dec. 1916	Neg.	4th [illegible] 1917	65
182	15th Dec. 1916	"	8th Jan. 1917	16
703	[illegible] 1917	"	7th Mar. 1917	28
343	23rd Jan. 1917	"	18th Jan. 1917	7
357	29th Jan. 1916	"	22nd Jan. 1917	23
241	3rd Jan. 1916	"	4th Jan. 1917	4
344	31st Dec. 1916	"	29th Jan. 1917	29
424	8th Jan. 1917	"	8th Jan. 1917	34
489	[illegible] 1917	"	8th [illegible] 1917	10
488	8th Jan. 1917	"	8th [illegible] 1917	8
588	[illegible] 1917	"	19th [illegible] 1917	10
704	8th [illegible] 1917	"	6th Mar. 1917	31
546	[illegible] 1917	"	[illegible] 1917	5
567	11th [illegible] 1917	"	[illegible] 1917	5
565	11th [illegible] 1917	"	[illegible] 1917	8
808	18th [illegible] 1917	"	13th Mar. 1917	70
643	18th [illegible] 1917	"	22nd [illegible] 1917	4
686	[illegible] 1917	"	8th Mar. 1917	27
701	26th [illegible] 1917	"	7th Mar. 1917	39
747	28th [illegible] 1917	"	16th Mar. 1917	13
801	[illegible] 1917	"	21st Mar. 1917	12
687	2nd Jan. 1917	"	4th Mar. 1917	7
841	6th Mar. 1917 and 30th Apr. 1917	"	18th [illegible] 1917	44 [illegible] 8
760	8th Mar. 1917	"	19th Mar. 1917	4
845	13th and 16th Mar. 1917	"	23rd Apr. 1917	25 and 47
1028	18th Mar. 1917	"	7th [illegible] 1917	10

IV. MENINGOCOCCUS CARRIERS

A large proportion of work upon cerebro-spinal fever has been associated with the study of meningococci from the naso-pharynx of carriers. The identification of meningococci with organisms isolated from the throat was a matter of great difficulty and even in the view of some impossible. This was due to the absence of any specific character by which the meningococcus might be differentiated from other very similar cocci commonly found in the throat. Many of these cocci are of course recognised at a glance as not being meningococci but others have been described which resemble the meningococcus closely. Owing to somewhat trivial biological differences they are, however, named and classified apart.

In the agglutination test as elaborated by Gordon we have a specific test by means of which the relationship of unknown cocci to meningococci may be established in the great majority of instances.

I. *Nasopharyngeal Strains of Meningococci.*

We have isolated over 500 strains of meningococci from the nasopharynx during the past season, and the following sections indicate their characters as found from a close study of 106 cultures.

(*a*) *Agglutination reactions and absorption tests.*—The whole of the strains classified below were provisionally diagnosed as meningococci, as a result of the positive agglutination test in a dilution 1 in 200. We may point out that in addition to the four "type" sera we have used as a routine Flexner's polyvalent anti-meningococcus serum, in the hope that this serum would prove to be suitable for use alone and thus save considerable labour. We also found that occasionally this serum gave a sharper agglutination of true meningococci than the type sera, and, further, nasopharyngeal strains were often met with which agglutinated with Flexner's serum but not with Gordon's. This phenomenon was not unknown with true meningococci upon certain occasions, and thus we hesitated to exclude these "Flexner" strains without further examination.

In the following table (12) the whole of these strains are arranged according to their agglutination reactions, and in the same table are given the results of confirmatory absorption tests:—

TABLE 12.

Agglutination and Absorption Tests of Nasopharyngeal Strains.

No.	Agglutination. Serum 1 in 200					Type by Absorption.			
	I.	II.	III.	IV.	F.	I.	II.	III.	IV.
					TYPE I AGGLUTINATION.				
4		0	0	0			0	0	0
6		0	0	0			0		0
8		0	0	0			0	0	0
887		0	0	0			0	0	0
898		0	0	0			0	0	0
230		0	0	0			0	0	0
178		0	0	0			0	0	0
288		0	0	0			0	0	0
					TYPE II AGGLUTINATION.				
54	0		0	0		0	0	0	0
135	0		0	0		0		0	0
173	0		0	0		0		0	0
384	0		0	0	+	0	+	0	0
40	0		0	0		0		0	0
183	0		0	0		0		0	0
865	0		0	0		0	+	0	0
577	0		0	0	+	0		0	0
284	+		0	0	+	0		0	0
			0	0		0		+	+

TABLE 12

No.	Accelerations. Stages I to IV					Type by Allocation			
	I.	II.	III.	IV.	F.	I.	II.	III.	IV.
						Type II			
568	0	—	0	0	—	0	—	1	0
584	0	—	0	0	—	0	—	0	0
603	0	—	0	0	—	0	—	—	0
607	0	—	0	0	—	0	—	—	0
447	0	—	0	0	—	0	—	0	0
486	0	—	0	0	—	0	—	0	0
487	0	—	0	0	—	0	—	—	0
502	0	—	0	0	0	0	—	0	0
573	0	—	0	0	—	0	—	0	0
648	0	—	0	0	—	0	—	1	0
						Type III			
888	0	0	—	0	—	0	1	—	0
						Type IV			
58	0	0	0	—	—	0	0	0	—
41	0	0	0	0	—	0	0	0	—
87	0	0	0	—	—	0	0	0	—
44	0	0	0	0	—	0	0	0	—
187	0	0	0	0	—	0	0	0	—
6	0	0	0	0	—	0	0	0	—
532	0	0	0	0	—	0	0	0	—
139	0	0	0	0	—	0	0	0	—
1184	0	0	0	0	—	0	0	0	—
218	0	0	0	—	—	0	0	0	—
811	0	0	0	0	—	0	0	0	—
773	0	0	0	—	—	0	0	0	—
11	0	0	0	0	—	0	0	0	—
1018	0	0	0	0	—	0	0	0	—
						Type I and III			
104	—	0	—	0	—	—	—	1	0
						Type II and IV			
431	0	—	0	0	—	0	—	1	—
407	0	—	0	—	—	0	—	0	—
913	0	—	0	0	—	0	0	0	—
951	0	—	0	—	—	0	0	0	—
859	0	—	0	0	—	0	0	0	—
916	0	—	0	0	—	0	0	0	—
84	0	—	0	—	—	0	0	0	—
458	0	—	0	0	—	0	0	0	—
886	0	—	0	—	—	0	0	0	—
177	0	—	0	—	—	0	0	0	—
1019	0	—	0	—	—	0	0	0	—
43	0	—	0	0	—	0	0	0	—
1019	0	—	0	—	—	0	0	0	—
1018	0	—	0	—	—	0	0	0	—
889	0	—	0	0	—	0	0	0	—
887	0	—	0	—	—	0	0	0	—
886	0	—	0	0	—	0	0	0	—

TABLE 12—*continued*.

No.	Agglutination. Serum 1 in 200.					Type by Absorption.			
	I.	II.	III.	IV.	F.	I.	II.	III.	IV.
	TYPE II AND IV AGGLUTINATIONS—*contd.*								
138	0	+	0			0	0	0	
389	0	-	0			0	0	0	
465	0	-	0			0	-	0	
	FEMALE AGGLUTINATIONS.								
270	0	0	0	0		0		0	0
61	0	0	0	0		0	0	0	
279	0	0	0	0		0		0	
52	0	0	0	0		0		0	0
185	0	0	0	0		0	0	0	0
400	0	0	0	0		0	0	0	0
183	0	0	0	0		0	0	0	0
195	0	0	0	0		0	0	0	0
80	0	0	0	0		0	0	0	0
383	0	0	0	0		0	0	0	
171	0	0	0	0		0		0	0
49	0	0	0	0		0	0	0	0
258	0	0	0	0		0	0	0	
856	0	0	0	0		0		0	0
681	0	0	0	0		0		0	0
311	0	0	0	0		0	0	0	0
671	0	0	0	0		0	0	0	0
456	0	0	0	0		0		0	0
864	0	0	0	0		0		0	0
780	0	0	0	0		0	0	0	
268	0	0	0	0		0	0	0	0
918	0	0	0	0		0	0	0	0
115	0	0	0	0		0	0	0	0
674	0	0	0	0		0		0	0
231	0	0	0	0		0	0	0	
203	0	0	0	0		0	0	0	
1,410	0	0	0	0		0	0	0	0
1,018	0	0	0	0		0	0	0	0
1,881	0	0	0	0		0	0	0	0
982	0	0	0	0		0	0	0	0
1,012	0	0	0	0		0		0	0
599	0	0	0	0		0	0	0	0
1,435	0	0	0	0		0	0	0	0
1,045	0	0	0	0		0	0	0	0
1,183	0	0	0	0		0	0	0	0
918	0	0	0	0		0	0	0	0
1,881	0	0	0	0		0	0	0	0
1,898	0	0	0	0		0	0	0	0
1,885	0	0	0	0		0		0	0
1,898	0	0	0	0		0	0	0	0
1,047	0	0	0	0		0	0	0	0

It will be observed that the cocci which agglutinate with only one of Gordon's four sera are proved by absorption tests to belong to the type indicated by the agglutination. Slight irregularities may be observed, namely, two type absorption in the case of Nos. 59 and 34 and no absorption with No. 54.

As with the cerebro-spinal strains, it is not uncommon to observe agglutination occurring with two related sera, namely, Types I and III, and IV and II. When this occurred with cerebro spinal strains it was shown that double agglutinations with Types I and III serum always indicated Type I cocci, or when with Type II and IV serum, Type IV cocci. This was also the case with the double agglutination of nasopharyngeal strains. Twenty-one cultures with Types II and IV agglutinations were examined, and only two, Nos. 431 and 407, showed more absorption of Type II agglutinins than Type IV. These two cases are not however quite conclusive since very little absorption occurred in either. We were unable to repeat the tests. The tables show a slight difference between nasopharyngeal and cerebro-spinal strains in the occurrence of double absorption among the double agglutination group of nasopharyngeal strains. No such examples are shown on the table of cerebro-spinal strains. Nevertheless this phenomenon has sometimes been met with among these strains. It will be understood that this absorption is very slight. We only found one instance through out the whole work of double agglutination taking place with unrelated sera.

This was a man, No. 684, who was found to be a carrier of a meningococcus like organism on March 7th, 1917. This coccus agglutinated completely with Type I, II and IV sera in a dilution of 1 in 200. On the 31st of the same month an identical result was obtained from a new swab. On 13th April a new swab was taken, and three separate colonies agglutinated with the following result :—

	Sera 1 in 200					
	Type I	Type II	Type III	Type IV	Flaxner	Control
[illegible] A		0	0			0
B		0	0	0		0
C			0			0

On the 26th April nine different colonies were investigated, as follows:—

	Sera 1 in 200.					
	Type I.	Type II.	Type III.	Type IV.	Flexner.	Control.
Colony 1	.	+	0	.	.	0
2	.	.	0	.	.	0
3	.	.	.	.	.	0
4	.	+	0	.	.	0
5	.	.	.	.	.	0
6	.	.	0	.	.	0
7	.	.	0	.	.	0
8	.	0	0	0	.	0
9	.	.	0	.	.	0

It is thus seen that upon two occasions a pure Type I coccus was cultivated from the throat, and, on all others, cocci giving the reactions of the Type I–III group and the Type IV–II group. These group reactions were clearly due to the presence of cocci belonging to Types I and IV. This was proved by absorption tests, colonies No. 5, 6 and 7 all absorbing the agglutinins for Type I and Type IV completely.

It is of interest to speculate upon the question whether this phenomenon was due to a double infection of the man's nasopharynx or whether the infection was due to an abnormal coccus which combined the characters of the two groups.

The fact that upon two occasions a pure Type I coccus was found suggests a double infection, but, on the other hand, it is shown (p. 57) that there is a marked antagonism between the two types in question, and it is unlikely that they would survive together in the nasopharynx. It is also unlikely that in fourteen different isolated colonies a type would have been found separate on two occasions only.

It seems to us to be more probable that these colonies contained one coccus only, namely, a mixed type, giving the characters of Types I and IV to a variable extent at different times.

Turning to the consideration of the strains shown on Table 12 as agglutinating with Flexner's serum only, forty one in number, we find several matters of interest. Some of these cocci absorb agglutinins from Gordon's type sera and some do not. Those which do belong exclusively to the IV–II group. Sixteen of the forty one cocci show absorption of "type" agglutinin, and of these eleven belong to Type II and five to Type IV.

From these results we are forced to conclude that, while Flexner's serum agglutinates true meningococci practically always, a positive result with this serum cannot be taken as being absolutely diagnostic of epidemic strains, because a very considerable proportion of throat strains which are agglutinated by it cannot be classified as Gordon's types by absorption tests.

On the other hand this serum undoubtedly indicates the presence of a certain number of Type IV II strains which would not be disclosed by Gordon's monovalent sera. It may be that this serum is prepared from a wider range of antigens than are found in this country, or, which is more probable, that the preparation of an animal with a number of different antigens leads to an excessive production of "group" affinities which overstep the boundaries of the pathogenic varieties.

From a general consideration of these results it is clear that large numbers of cocci exist in the nasopharynx which do not differ in any important particular of agglutination or absorption from true cerebro-spinal strains, and thus these cocci must be accepted as epidemic meningococci. On the other hand, it is necessary to bear in mind that a number of cocci also exist in the nasopharynx which have much similarity to meningococci in cultural tests, and which may indeed be undeveloped members of the meningococcus group. They are, however, sufficiently atypical to fail to react to the specific tests to which epidemic meningococci react, and thus cannot be accepted as such for practical purposes.

(b) Fermentation tests.—Fermentation tests have been carried out on forty-four cultures from the nasopharynx which had been selected in the ordinary routine as being probably meningococci. A few cultures of gram negative cocci were also included which, from the appearance of the colonies, did not suggest meningococci. The sugars used were glucose, maltose and saccharose (G. M. S.). The results are given in the following table:

TABLE 13.

Fermentations of Nasopharyngeal Cocci.

No. of Strain	Type	1 Day			2 Days			3 Days			4 Days		
		G.	M.	S.	G.	M.	S.	G.	M.	S.	G.	M.	S.
3				0			+			0			0
38	+	0		0			+			0			+
45	+	0	+	0			+			0			0
34	IV			0			0			0			0
43	IV			0			+			+			+
71	IV	0		0			+			0			0
40	IV			0			0			0			+
41	IV	0	0	0	0	0	0	0		0			0
80	IV	0		0			0			0			0
118	+			0			0			0			0
120	+	0	0	0			+			0			+
35	+	0	+	0			+			+			+
33	+	0	0	0			0			+			+
63	IV			0			0			0			0
72	+		0	0			0			0			0
133	+			0			0			0			+
	+			0			0			0			+

TABLE 13. *continued.*

No. of Strain.	Type.	1 Day.			2 Days.			3 Days			4 Days		
		G.	M.	S.	G.	M.	S.	G.	M	S.	G.	M	S.
383	IV (Flexner)			0			0			0			0
203	IV (Flexner)			0	+		0			0			0
155	II	0	0	0			0			0			0
40	II			0			0			0			0
153	II	0	0	0			0			0			0
107	II	0	0	0	0		0			0			0
414a	II	0	0	0			0			0			0
457	II	0	0	0			0			0			0
485	II			0			0			0			0
306	II	0		0			0			0			0
268	II	0	0	0			0			0			0
253	II	0		0			0						0
52	II (Flexner)	0		0			0			0			0
64	Flexner (N.A.)			0			0			0			0
61	Flexner (N.A.)	0		0	+	+	0			0			0
113	Flexner (N.A.)	0	0	0	+		0	+		0			0
623	Flexner (N.A.)	0	+	0	0	+	0			0			0
196	No agglutination			0	+		0						0
110	No agglutination		0	0			0			0			0
117	No agglutination	0		0	+	+	0			0			0
1,250	No agglutination	0		0	+		0						0
10	No agglutination			0	+	+						+	+
238	No agglutination	0		+	+			+					
487	No agglutination	0		0			0						
304	No agglutination	0	0	0	0	0	0	0	0	0	0	0	0
1,247	No agglutination	0	0	0	0	0	0	0	0	0	0	0	0
1,249	No agglutination												

Note.—In the column denoting the type, the word "Flexner" attached to a "type" numeral indicates that the culture agglutinated with Flexner's serum only, but absorbed the type tested. The figures "N.A." mean "not absorbing" the Flexner strains which could not be agglutinated with types.

+ = good production

+ = light but positive production

0 = no change

In the above table it is seen that

3 Type I strains fermented both glucose and maltose, but not saccharose.

12 Type IV strains fermented both glucose and maltose, but not saccharose.

4 Flexner strains (absorbing Type IV) fermented both glucose and maltose, but not saccharose.

10 Type II strains fermented both glucose and maltose, but not saccharose.

1 Flexner strain (absorbing Type II) fermented both glucose and maltose, but not saccharose.

4 pure Flexner strains (non-absorbing) fermented both glucose and maltose, but not saccharose.

4 Non-agglutinating strains fermented both glucose and maltose, but not saccharose.

4 Non-agglutinating strains fermented glucose, maltose and saccharose.

2 Non-agglutinating strains fermented neither glucose, maltose nor saccharose.

Thus thirty strains of "epidemic" meningococci were examined and all gave the same fermentation reactions as strains from the cerebro-spinal fluid.

In addition to these, four strains which agglutinated with Flexner's serum but did not absorb agglutinins for "epidemic" strains and also four strains of meningococcus-like bacteria which did not agglutinate with any serum, also gave the same fermentation reactions.

SIX cultures in which the colonies more or less resembled those of the meningococcus, but did not agglutinate, gave different fermentation reactions from the meningococcus.

It is thus clear that Gram-negative cocci which give the fermentation reactions of meningococci are not all meningococci in the sense that they are epidemic strains, although they may be members of a meningococcus group.

We were unable to demonstrate any differentiation of naso-pharyngeal cocci into "glucose preferring" strains, as was the case with the cerebro-spinal fluid strains.

(c) *General characters.* The general characters of naso-pharyngeal meningococci appear to us to be identical with those of cerebro-spinal strains. Variation in character does not in our experience occur to a greater extent among the former than the latter. It is, however, possible that small relatively opaque colonies in the primary culture are commoner from the naso-pharynx than from the cerebro-spinal fluid.

2. *The frequency of Meningococci in the Naso-pharynx.*

Hitherto the majority of examinations of throats for meningococci have been made in men who have been more or less in contact with a case of the disease, and it has often been assumed that any positive cases found have had some relationship with the case. A smaller number of examinations of non-contacts have, however, indicated a certain proportion of positives among the general population, and therefore it has become uncertain to what extent there is any causal connection between case and positive contacts.

Thus in a series of 650 non-contacts of all ages attending the out-patient department of St. Bartholomew's Hospital and examined bacteriologically in the laboratory of the Local Government Board

by Eastwood and Griffith, meningococci were found 92 times, = 13·52 per cent., the cases being distributed as follows :—

No. of Cases.	Period of Examination.	Positive Cases
100	March 29th, 1915—April 19th, 1915	2
100	April 19th, 1915—May 6th, 1915	7
100	May 6th, 1915—June 7th, 1915	8
100	June 7th, 1915—June 24th, 1915	7
80	June 24th, 1915—July 22nd, 1915	9
100	July 1st, 1915—July 24th, 1916	9
100	April 6th, 1916—June 5th, 1916	54
680		92

(Reports to the Local Government Board, 1916, New Series, No. 110, p. 38, and 1917, No. 114, p. 7.)

We have had the opportunity of paying great attention to the examination of non contacts, and every day throughout the year we have examined the throats of "new entries" into the Navy. We have thus been able to carry out an actual census of carriers through all seasons.

The determination of the type of the nasopharyngeal strain often has an important bearing upon the epidemiology of the cases.

(a) The results of the examination of all types of person.

The following table (14) gives the actual figures and results of the examination of the throats of all "new entries," together with the type of coccus in the cerebro-spinal fluid of all cases and the types in the nasopharynx of all contacts of these cases. All results are given in a chronological form, and calculated per week from the beginning of the season.

Table 14.

Total Number of New Entries, Cases and Contacts examined during one year, with the Types of Mycobacterium found.

Fifty [illegible] of Ulcers (type) omitted. II. IV Types counted as IV.

1917	Type	New Entries							Cases							Close Contacts (Two Sexes)							Extensive Contacts (Two Sexes)						
		Total	Exudative Type						Total	Exudative Type						Total	Exudative Type						Total	Exudative Type					
			I.	II.	III.	IV.	V.	?		I.	II.	III.	IV.	V.	?		I.	II.	III.	IV.	V.	?		I.	II.	III.	IV.	V.	?
1916																													
[illegible]		243	1	1	1	1	0	1	1	1	0	0	0	0	0	8	1	1	0	0	0	1	25	0	0	0	0	0	0
[illegible]		227	1	2	0	1	0	7	2	2	0	0	0	0	0	14	2	0	0	0	0	0	20	1	1	0	3	0	3
[illegible]		305	4	2	1	5	1	3	1	1	0	0	0	0	0	16	1	1	0	0	0	0	15	0	1	0	0	0	0
[illegible]		322	4	9	1	2	1	0	1	0	1	0	0	0	0	4	0	0	0	1	0	0	0						
[illegible]		221	1	1	0	1	1	0	1	0	0	1	0	0	0	5	0	0	0	0	0	0	4	1	0	0	0	0	0
[illegible]		285	4	5	0	5	5	0	3	?	0	1	0	0	0	22	2	1	0	1	0	0	23	0	0	0	1	0	0
1917																													
[illegible]		333	4	5	0	5	4	0	0																				
[illegible]		428	6	6	0	1	2	0	2	1	0	0	1	0	0	15	0	1	0	1	0	0	55	1	3	0	3	0	0
[illegible]		318	1	9	0	3	1	0	2	0	1	0	1	0	0	15	0	3	0	0	1	0	33	0	1	0	0	0	0
[illegible]		364	5	7	1	7	1	0	2	0	1	0	1	0	0	12	0	0	0	2	0	0	33	0	1	0	0	1	0
[illegible]		330	1	4	0	6	2	0	3	2	1	0	0	0	0	14	0	2	0	1	0	0	37	0	1	1	2	0	0
[illegible]		486	2	13	6	8	2	0	3	2	0	0	1	0	0	26	0	2	0	2	1	0	67	0	3	0	1	0	0
[illegible]		461	3	11	0	4	1	1	5	3	1	0	1	0	0	31	0	3	0	3	0	0	125	0	3	0	4	1	0
[illegible]		429	1	7	0	2	6	0	1	0	1	0	0	0	0	8	0	1	0	0	0	0	4	0	0	0	0	0	0
[illegible]		472	1	8	0	8	4	1	6	3	2	0	0	0	1	36	1	2	0	0	0	0	64	2	4	0	2	0	0
[illegible]		369	0	4	0	2	1	2	3	1	1	0	0	0	0	11	0	1	0	0	0	0	69	0	9	0	2	0	0
[illegible]		379	0	12	0	4	1	0	1	1	0	0	0	0	0	6	1	0	0	0	0	0	0						
[illegible]		408	1	5	0	1	1	1	0																				
[illegible]		137	0	1	0	1	0	0	2	1	1	0	0	0	0	15	0	3	0	0	0	0	81	0	3	0	4	0	0
[illegible]		151	0	2	0	0	0	0	1	1	0	0	0	0	0	3	0	0	0	0	0	0	18	0	1	0	0	0	0
[illegible]		285	0	6	1	0	1	0	1	0	1	0	0	0	0	6	0	1	0	0	0	0	11	0	0	0	0	0	0
[illegible]		243	0	2	0	1	1	0	0																				

1917																																
Apl 27th-May 3rd	173	0	5	0	0	1	0	1	0	0	0	1	0	0	2	0	0	0	0	0	0	43	0	0	0	0	0	0				
May 4th-10th	345	0	1	0	0	3	0	0																								
May 11th-17th	267	1	3	0	1	1	0	0																								
May 18th-24th	236	0	8	0	0	3	0	0																								
May 25th-31st	174	0	7	0	2	3	0	1	1	0	0	0	0	0	6	0	0	0	0	0	0	19	0	1	0	1	0	0				
June 1st- 7th	360	0	4	0	2	2	0	1	1	0	0	0	0	0	7	0	1	0	0	0	0	0										
June 8th-14th	366	0	8	0	1	2	0	0																								
June 15th-21st	217	0	1	1	0	1	0	0																								
June 22nd-28th	434	0	8	6	2	2	0	1	0	0	1	0	0	0	12	0	0	0	0	0	0	63	0	0	0	0	0	0				
June 29th- July 5th	314	0	0	0	0	1	0																									
July 6th-12th	332	0	2	0	0	0	0																									
July 13th-19th	279	0	0	0	0	0	0																									
July 20th-26th	278	1	2	0	0	1	0																									
July 27th-Aug 2nd	446	0	2	0	0	1	0																									
Aug 3rd- 9th	235	0	0	0	0	1	0																									
Aug 10th-16th	260	0	1	0	0	0	0																									
Aug 17th-23rd	244	0	0	0	0	0	0																									
Aug 24th-30th	241	0	2	0	0	0	0																									
Aug 31st-Sept 6th	213	0	0	0	0	1	0																									
Sept 7th-13th	227	0	0	0	1	0	0																									
Sept 14th-20th	264	0	0	0	0	0	0																									
Sept 21st-27th	269	0	1	0	0	0	0																									
Sept 28th-Oct 4th	255	0	0	0	0	1	0																									
Oct 5th-11th	226	0	1	0	0	2	0																									
Oct 12th-18th	223	0	0	0	0	1	0																									
Oct 19th-25th	258	0	2	0	0	1	0																									
Oct 26th-Nov 1st	225	0	2	0	0	1	0																									
Nov 2nd- 8th	242	0	2	0	0	0	0																									
Nov 9th-15th	217	0	0	0	0	1	0																									
Nov 16th-22nd	259	0	1	0	2	2	0																									
	14,618	41	191	12	73	68	16	44	23	11	3	6	0	1	297	8	23	0	11	2	1	809	5	32	1	24	2	3				
		401							44							45							67										

In compiling this table it has been necessary to make certain corrections.

(1) We have omitted rather over 50 per cent. of the Flexner types from the table on the ground that, as shown on p. 39, at least half of such strains are not "epidemic" meningococci. To establish this fact by absorption tests was clearly impossible in all cases.

(2) Those cases which agglutinated with two sera have been classed under one type. As shown on p. 48, cases agglutinating with Types I and III sera belong to Type I, while cases agglutinating with Types II and IV sera probably all belong to Type IV. They have, therefore, been entered according to this plan, it being impossible to make absorption tests in so many cases.

It should be observed that close contacts were always examined twice, and remote contacts once. These two series are therefore not directly comparable.

(b) The results of the examination of "new entries." The "new entries" were men from all parts of the country and of all ages up to 41, but they also included a few hundreds of older men who were recruited for a certain purpose.

They were examined within a very short time of entry into barracks, usually twenty-four hours after, but sometimes as long as four days. The longer interval was unavoidable during the earlier part of the season owing to pressure of work before the system was completely organised.

During the latter half of the season special efforts were made to keep these men segregated from the rest of the barracks before the swab was taken. Up to that time there was a partial and ineffective segregation only.

On the whole it is considered that these men can have been influenced by service conditions to a very slight extent, and thus may be reckoned to be a fair sample of the general population.

It will be observed from the table that 14,618 men, this type were examined during the year, and that 401 carriers of meningococci were found (= 2·7 per cent.).

This figure alone has however little significance since it is obvious that a marked seasonal fluctuation in the incidence exists. In Chart 3 the seasonal incidence is shown graphically, the above figures being calculated as percentage positive per week during the season. Those cases classed as ? (unknown type) in the table are here omitted.

Several points of interest may be observed in this chart.

In November, 1916, when the examinations were started, there were already a number of carriers among "new entries." This number increased up to a summit in January after which the incidence tended to diminish until April. During May, however, there was actually a greater incidence than at any other time. During June, July and August the number of

positive carriers fell away to zero, and remained at or about this level. The weekly percentage never reached 7, but on three occasions fell between 6 and 7.

A further analysis of this curve, to show the fluctuations in the different types of meningococci in the throats during this period, is also interesting (Chart 4).

The unknown types are omitted from these curves also. With regard to the other types we have thought it inadvisable to subdivide them into the four but have retained them in two groups, namely Types I and III and Types IV and II. Too much error, owing to the smallness of the numbers, would have been involved in a further subdivision. With regard to the Flexner strains these have all been included with the Types IV and II strains, on the grounds indicated on p. 39.

From these curves it is seen that the epidemic of Type I and III strains was present in November, 1916, and maintained a steady rate until the end of February. At this time the epidemic ceased, and sporadic instances only of this infection were observed after this date.

With regard to the Type IV and II strains these were much commoner throughout, and maintained their incidence curve for a considerable time after the Type I and III strains had disappeared. During the end of March and the beginning of April the curve fell somewhat, only to be followed by a pronounced rise in May and June. After this exacerbation the curve fell to zero, and afterwards maintained a very low rate. The most marked features of this chart are, therefore, the two well maintained exacerbations in the "carrier rate" of the two groups of meningococci. The Type IV II group appears to be constantly present throughout the year in small numbers, and then, during winter and spring, a very marked increase in the rate takes place. In the present instance there is some probability that the rise in the early summer is abnormal, and that the epidemic usually ends in April. The Type I III group runs a similar course, but being much more scarce, practically dies out in summer and autumn altogether. Only sporadic examples of these types are observed after February.

(c) *The result of the examination of contacts.*—Throughout this work contacts of a case are reckoned to be the members of the "mess" of the case.

The men who sat at meals on each side of the case and opposite, and any special friends, were classed as "close" contacts. They usually numbered six men. The rest of the mess, namely, about seventeen men, and anyone else who had been in direct contact were "remote" contacts.

That this classification is purely artificial is obvious when the organisation of a naval barracks is considered. At the Royal Naval Barracks at Portsmouth, whence came the majority of our cases, the men lived in "rooms" of 144 persons. These

rooms are divided into two halves by a metal rack, on which are stowed the men's kit and hammocks. There is free communication by men round the ends of the rack, and of course it does not affect the passage of bacteria anywhere. Down the centre of each half room runs a row of three tables, accommodating (at that time) twenty-four men at each. Each table is a "mess" or unit for domestic organisation and the hammocks are slung at night over the area occupied by each mess or table. In such a room the actual members of a man's mess appear to be very little more in contact than the rest of the room.

The close contacts of the cases were segregated and immediately swabbed. The positives were then removed and the negatives swabbed again before discharge from quarantine.

The remote contacts were not quarantined, but were all swabbed once only on the day following the diagnosis of the case.

When a case occurred in a ship in harbour the same organisation held, but in these there was a great difference between the degree of contact and that present in the barracks.

The ships were acting as "overflow ships" to the barracks and were old, but quite apart from the age of the ship the facilities for infection must always appear to be excellent on the mess decks.

In the barracks, on the other hand, the rooms are modern and roomy. They have the appearance which is commonly associated with healthiness.

The type of man examined was almost exactly the same as the "new entries" in fact, many had already been swabbed shortly before upon entry.

It will be seen from Table 14 that 297 close contacts were examined, and 809 remote.

15·4 per cent. of the close contacts were positive, and 8·2 per cent. of the remote. These figures do not give an accurate comparison between the two types, since, as stated, the close contacts were examined twice. The percentage of close contacts positive when calculated upon the first swabs is 13·4, and thus there is only a slightly greater incidence of positives among close contacts than among remote.

The figures involved are too small to draw a curve of the seasonal incidence, but it will be tolerably clear that a seasonal incidence exists among carriers of a similar type to that demonstrated for "new entries."

3. *A comparison between the Type of Coccus infecting the Case and that found in the Nasopharynx of Contacts.*

When a case of cerebro-spinal fever occurs and swabs are taken from the throats of the contacts, a certain number of these contacts are found to be carrying meningococci, and it is often assumed that there is necessarily a causal connection between the case of fever and the positive contacts. By determining

the "types" of the different cocci we have, however, been able to show that this is far from being the case, as was to be expected.

For the purpose of the following calculations only pure "Gordon" types are counted, and in the case of close contacts only the first swab.

We have tabulated the positive contacts of every case according as each one was infected with a coccus of the same type as the case, or different. The result is as follows :—

TABLE 15 (modified from Table 14).

Showing the Relationship between the type of the Case and the type of the Contacts.

Date.	Close Contacts.				Remote Contacts.			
	Total.	Positive.	Positive same type.	Positive different type.	Total.	Positive.	Positive same type.	Positive different type.
1916								
Nov. 24th–30th	8	2	1	1	25	0	..	.
Dec. 1st–7th	14	1	1	..	20	3	1	2
Dec. 8th–14th	16	1	1	..	15	1	...	1
Dec. 15th–21st	4	1	...	1	0	.	...	...
Dec. 22nd–28th	5	0	...	...	4	1	...	1
Dec. 29th–Jan. 4th, 1917	22	2	2	1	23	4	...	4
Jan. 12th–18th	15	2	..	2	55	7	3	4
Jan. 19th–25th	15	3	1	2	33	1	1	
Jan. 26th–Feb. 1st	12	2	1	1	33	1	1	.
Feb. 2nd–8th	19	3	1	2	37	4	...	4
Feb. 9th–15th	20	2	..	2	67	4	..	4
Feb. 16th–22nd	31	3	1	2	125	7	1	6
Feb. 23rd–Mar. 1st	6	1	1	..	4	0	..	.
Mar. 2nd–8th	36	2	1	1	64	8	2	6
Mar. 9th–15th	11	0	..	..	60	11	5	6
Mar. 16th–22nd	0	0	..	..	0	.	...	...
Mar. 30th–Apr. 5th	15	3	1	2	81	7	3	4
April 6th–12th	3	0	..	..	18	1	..	1
April 13th–19th	6	1	1	..	11	0	..	.
April 27th–May 3rd	2	0	..	..	44	0	..	..
May 25th–31st	6	0	..	..	19	2	..	2
June 1st–7th	7	1	..	1	0	..	..	..
June 22nd–28th	12	0	..	..	63	0	..	..
Totals ...	297	31	15	16	869	69	17	49
Percentage of Positive contacts	(10·4	5·1	5·4		7·9	2·1	5·1	

There are several results of importance disclosed in this table.

Over half the positive close contacts of a case have a meningococcus in the nasopharynx (52·4 per cent.) but no direct relation to the case being of a different type.

Close contacts are more often infected with a coccus of the same type as the case than remote contacts (i.e. in a proportion of 5·0 to 2·1).

The number of men carrying an indifferent coccus is exactly the same whether they are close or remote contacts.

It is clear from these figures that there are a number of positive contacts in the neighbourhood of a case which have no direct relation to the case and simply represent the normal distribution of carriers in the community in which the case occurred. Further, some of the remote contacts who happened to carry the same type as the case (2·1 per cent.) must also really belong to the normal carrier population, and therefore the number of positive remote contacts who have any real causal connection with the case must be practically *nil*.

In other words, the positive remote contacts can hardly represent anything more than the carrier rate which happened to prevail in that community at the time of the onset of the case.

The carrier rate, therefore, in the vicinity of a case must be at least 5·5 per cent., and probably 7 per cent. It is comparable to a rate of 3·4 per cent. over the same period among "new entries," representing the general population. It is made up of men who cannot have obtained the infection from the case, and therefore it follows that in the vicinity of a case there must be a *pre existing* high rate for all types of coccus.

We have insufficient material on which to calculate the rate among unaffected messes, and therefore we do not know whether the high rate of 7 per cent. is general in the barracks or only associated with a case.

Turning to the close contacts we find that these are more often of the same type as the case than the remote contacts, but indeed the difference is not great (5·0 : 2·1). It is however justifiable to assume from this figure that there is more causal connection between the case and a close contact than between the case and a remote contact.

4. *The length of Time carriers remain Positive.*

When any man was found to be carrying meningococci in the nasopharynx he was transferred to a special isolation camp, where he lived under canvas. The camp was divided into three separate sections, two of which were occupied by carriers. One of these was the "positive" section occupied by men who were actually demonstrated to have meningococci in the throat, and the other the "negative" section occupied by the carriers who were for the moment negative.

All carriers were examined once a week.

During the first half of the season carriers were returned to barracks after they had registered two negatives in the camp; they were then required to show two more negatives before they could be drafted. It was, however, found that so many men relapsed after returning to barracks that for safety and convenience all four negatives were registered in the camp. On discharge, the men were then considered cured.

The following figures (Table 16) relate to 360 men, all carriers of pure "Gordon" types, "Flexner" types being excluded. They were all under various forms of local antiseptic treatment. These men are classified according to the number of months they remained in quarantine. The average time in each monthly group is assumed to be half way through the month. Thus, men falling in the 4–5 months group are assumed to have been in the camp for 4½ months. From this the actual period positive is obtained by subtracting the three weeks which the men pass in the final negative section. A man in the 4–5 months group is therefore assumed to have been positive for fifteen weeks.

TABLE 16.

The length of Time carriers remain Positive.

Monthly "Groups."	No. of Men Quarantined for these periods.	No. of Months lost in Quarantine.	No. of *Weeks* these men were Positive.
1	126	126	126
1–2	86	129	258
2–3	71	177	497
3–4	38	133	418
4–5	25	112	375
5–6	8	44	152
6–7	4	26	92
7–8	2	15	54
	360	762	1,972

Note.—Several of the most chronic carriers were invalided while still positive, and also some of the men would no doubt have remained positive for longer than eight months.

In the 3–4 month group 3 men were invalided
" 4–5 " 1 man was "
" 5–6 " 1 man was "
" 6–7 " 3 men were "
" 7–8 " 2 men were "

It will be seen that 360 men were under observation, and the total time lost in quarantine by these men was 762 months, which is equivalent to a loss to the Navy of the work of five men for twelve years. The actual time during which the men were demonstrated carriers is 1,972 weeks, or 493 months. Therefore, each man on the average remained positive for 1·3 months.

This average figure (1·3 months) may conveniently be taken as the dividing line between mild and chronic carriers: that is to say, the men in the categories 1 month and 1 to 2 months may be taken as *mild* carriers and over this time *chronic* carriers.

There were 212 mild carriers for a total period of 384 weeks: thus the average time positive for a mild carrier is 0·45 months.

Chronic carriers (148 men) remained positive for 1,588 weeks, or chronic carriers remained positive, on the average, for 2·6 months.

From these figures it appears that more than half the demonstrated carriers were mild, and only remained positive a fortnight. If the analysis is carried a little further it is seen that 126 men were positive for 1 week only, or at one examination only. Thus, exactly one third of the men were very transient carriers.

The figures for chronic carriers are to some extent vitiated by the fact that the most chronic were excluded out of the Service. It is, however, quite common to find men persisting as carriers for several months.

5. *The relation between the Type of Coccus and the Length of Time carriers remain Positive.*

The following calculations are based on a special series of men, who were particularly chronic carriers, and in which the exact limit of carrying one coccus was proved beyond doubt.

Various inconsistences in totals will be observed between these figures and those of the last section; this depends upon several factors.

(1) The time of carrying here is calculated from the time of the first positive swab to the time of the last positive swab. Therefore, a man positive for two months in this section would usually come into the category "3-4 months in quarantine" of the last section.

(2) All carriers who changed their type or carried types undetermined by absorption tests, when doubtful, are here omitted.

(3) Cultures from the chronic carriers who gave persistent positives when examined at weekly intervals were not subjected to agglutination tests on every occasion but only at intervals. A number of men are therefore excluded here, or their period of carrying shortened somewhat because some of their final positive tests were not proved by agglutination.

The following table (17) shows the chronic carriers grouped according to the type of meningococcus present in the naso-pharynx.

Table 17.

The total number of Men who carried Cocci of various types for Two Months or over.

Type I.		Type II.		Type III.		Type IV.	
No. of Men.	Length of Time (months).	No. of Men.	Length of Time (months).	No. of Men.	Length of Time (months).	No. of Men.	Length of Time (months).
1	3	8	2	0	...	8	2
...	...	2	2¼	...	...	2	2½
...	...	4	2½	...	...	8	3
...	...	9	3	...	...	3	4
...	...	2	3¼	...	...	3	5
...	...	1	3½	...	...	1	5½
...	...	1	3¾	...	...	1	5¾
...	...	1	4	...	...	1	6
...	...	1	4½	...	...	1	7
...	...	1	4¾	...	...	...	...
...	...	1	5	...	...	...	...
...	...	1	5½	...	...	...	...
1	3	32	94¼	0	...	28	96¼

Total number of men found to be carriers of the various types (see also Table 14, p. 44):

Type I.— 54 men.
" II.—246 "
" III.— 13 "
" IV. 108 "

Percentage of these shown above to be chronic carriers:

Type I.— 1·8
" II.— 13
III.— 0.
IV.— 25·9

It will be seen from this table that in the case of those men infected with Type IV cocci the percentage which became chronic is much higher than in the case of those infected with Type II—25·9 per cent. against 13 per cent. Among the Type I carriers only one became chronic, giving a percentage of 1·8.

As far as Type I is concerned this result bears out the idea that this organism is essentially a pathogenic type, and is less likely than are Types II and IV to lead a prolonged existence in the nasopharynx.

Type III was only isolated from the nasopharynx on thirteen occasions, and none of these were chronic carriers. The numbers are, however, too small to form any conclusions upon.

6 *Cross Infection of Carriers leading to a Change in the type of the Meningococcus infecting the Nasopharynx*

In order to be able to prove that a man has been cross infected from another carrier, it is necessary to establish definitely that he has become a carrier of a type of coccus different from that found previously in his nasopharynx. This cannot be done by agglutination when the two cocci in question are closely related. It is, for instance, difficult to be quite certain by agglutination that a Type II coccus has been replaced by a Type IV, because the latter is often agglutinated by Type II serum. To make quite certain it would be necessary to carry out absorption tests, but this is not practicable as a routine and therefore we leave out in this place a number of possible examples of the phenomenon.

In Table 18 details are given of nine instances of cross infection. In six cases Type I was replaced by Type IV, in two Type IV was replaced by Type I, and in one Type I was replaced by Type II. There is thus some reason to suppose that Type IV, in addition to being more chronic in the nasopharynx, is actually liable to supplant Type I in the nasopharynx.

Table 18.

Cross-infection of Carriers.

Case No. 284	No. of Swab	1	2	3	4	5	6	7	8	9	10
	Place	B.	C.	C.	C.	C.	C.	C.	C.	B.	B.
	Date	3	14	14	[illegible]	29	1	2	12	24	26
	Result	Pos.	Pos.	Neg.	Pos.	Pos.	Pos.	Neg.	Neg.	Neg.	Neg.
New Laid.	Type	IV.	—	—	—	I.	I.	—	—	—	—

Case No. 287	No. of Swab	1	2	3	4	5	6	7	8	9	10
	Place	B.									
	Date	14	19	26	1	5	14	22	2	5	28
New Laid.	Result	Pos.	Neg.	Neg.	Neg.	Neg.	Pos.	Neg.	Neg.	Neg.	Neg.
	Type	I.	—	—	—	—	IV.	—	—	—	—

Case No. [illegible]	No. of Swab	1	2	3	4	5	6	7
	Place	B.	C.	C.	C.	C.	C.	C.
	Date	24	29	1	2	5	18	26
New Laid.	Result	Pos.	Neg.	Pos.	Neg.	Neg.	Neg.	Neg.
	Type	IV.	—	I.	—	—	—	—

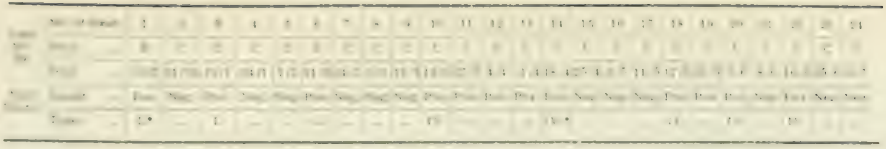
Case No. 191	No. of Swab	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Place	B.	C.	C.	C.	C.	C.	C.	C.	C.	C.	C.	C.	C.	C.	C.	C.
	Date	23	12	5	12	19	26	1	9	16	23	30	7	14	21	28	4
Case Laid.	Result	Neg.	Pos.	Pos.	Pos.	Pos.	Pos.	Pos.	Pos.	Neg.	Pos.	Pos.	Pos.	Pos.	Pos.	Pos.	Neg.
	Type	—	I.	—	—	—	—	—	—	—	—	—	—	—	IV.	—	—

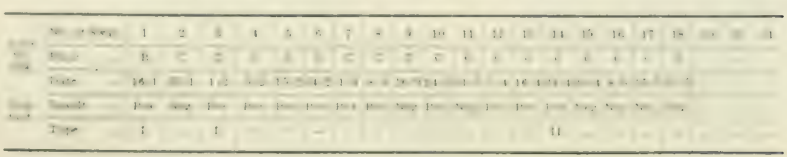
Case No. [illegible]	No. of Swab	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
	Place	B.	C.	C.	C.	C.	C.	C.	C.	C.	C.	C.	C.	C.	C.	C.	C.	C.	C.	C.	C.	C.	C.	C.	C.	C.	C.	C.
	Date	10	17	24	31	7	14	21	28	5	12	19	26	2	9	16	23	30	7	14	21	28	4	11	18	26	4	6
New Laid.	Result	Pos.	Pos.	Pos.	Pos.	Pos.	Pos.	Pos.	Pos.	Pos.	Pos.	Pos.	Pos.	Pos.	Pos.	Pos.	Neg.	Neg.	Pos.	Neg.	Neg.	Pos.	Neg.	Pos.	Neg.	Pos.	Pos.	Neg.
	Type	I.	—	—	I.	—	IV.	—	—	—	—	IV.	—	—	—	—	—	IV.	—	—	—	IV.	—	IV.	—	IV.	—	—

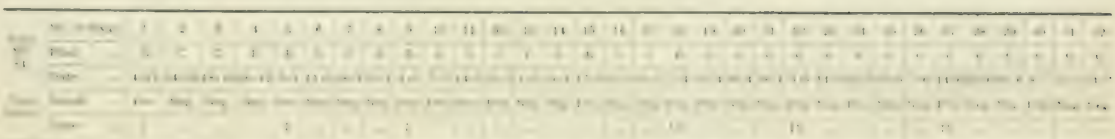
(See Discussion on following page.)

TABLE 18

—Concluded.







7. *Antagonism between the Various Types of Meningococci in the Nasopharynx.*

In previous sections it has been shown that Type IV cocci are more liable to persist in the nasopharynx for a longer time than other types. It has also been shown that Type IV cocci commonly replace other cocci in the throat. It therefore appears that Type IV cocci are to some extent antagonistic or destructive to other types of cocci.

We have attempted to demonstrate this experimentally.

Experiment :—Suspensions of equal opacity were made up of Types I, II and IV. Equal quantities of these were mixed together, namely, Types I and IV ; Types I and II ; and Types II and IV. Each of these mixtures were then cultivated upon Hb. serum agar, and the resulting culture (A) subcultured and made into a suspension. The subculture (B) was similarly treated, and thus of each mixture there were three suspensions, A, B and C, representing three subcultures. These suspensions were agglutinated with the four "type" sera (1 in 200), and their power of absorbing "type" agglutinin tested.

		Agglutinations. Type I.	II.	III.	IV.	Absorptions. Type I.	II.	III.	IV.
Types I and IV	A	.	0	0	.	.	0	0	. .
	B	.	.	.	—	.	0	0	. .
	C	0	0	0	.	0	0	0	. . .
Types I and II	A	.	.	0	0	. .	. .	0	0
	B	—	—	—	—	. .	. .	0	0
	C	.	.	0	0	. . .	. . .	0	0
Types II and IV	A	0	0	0	0	0	. . .	0	. . .
	B	—	—	—	—	0	. .	0	. . .
	C	0	0	0	.	0	0	0	. .

The experiment shows that Type IV displaced Types I and II from the culture entirely, while Types I and II grew together with equal vigour. It therefore appears to support the view that Type IV has some power of overcoming infections by the other types.

8. *The Pathogenicity of the Various Types of Meningococci in the Nasopharynx.*

It is possible to bring forward a quantity of indirect evidence which strongly suggests that the power of producing cerebro-spinal fever exercised by the various types of meningococci in the throat is very different.

If each of the four types of meningococci were equally liable to infect, the type which produced most cases should be that which is predominant in the nasopharynx. This is, however, far from being the case.

The following figures are taken from Table 14, from the week beginning November 24th, 1916, to the week beginning June 22nd, 1917.

During this time there were 44 cases, and in 43 of these the type was determined. They were as follows:—

Type	I.— 23 cases	= about 53 per cent	
,,	II.—11	,,	25 ,,
,,	III.— 3	,,	7 ,,
,,	IV.— 6	,,	14 ,,

That is to say, there were twice as many Type I cases as Type II.

Now take the incidence of these types in the general population as represented by the "new entries." During this period 292 were found positive, and among these the types were as follows:—

Type	I.— 40 instances	= about 13 per cent of the positives	
,,	II.—170 ,,	= about 58 per cent of the positives	
,,	III.— 12 ,,	= about 4 per cent of the positives	
,,	IV.— 70 ,,	= about 23 per cent of the positives	

That is to say, there were over four times as many carriers of Type II as Type I, and yet Type I cases were [illegible] as Type II.

This fact seems to show that Type I cocci are much more effective producers of disease than Type II cocci. On similar grounds Types III and IV would seem to be less infective than Type I, but more infective than Type II, the phenomenon is not so striking in this instance, however, and the number of cases is hardly sufficient to warrant any very definite conclusion.

Against these deductions concerning the infectivity of Type I cocci, it may be argued that the cases of meningitis do not arise among the general population, but in situations where there is a concentration of nasopharyngeal meningococci (*vide* p. 40), and where, perhaps, Type I predominates.

If, however, Type I cocci were of equal pathogenicity to Type II, in order to produce the number of cases due to Type I which occurred, the number of Type I cocci in the throat would have to be twice as great as Type II around a case. This however, is found not to be so.

Among the 42 positive close contacts we found:—

Type	I.— 8 cases	= about 19 per cent of the positives	
,,	II.— 23 ,,	= ,, 55 ,,	
,,	III.— 0 ,,	= ,,	
,,	IV.— 11 ,,	= ,, 26 ,,	

Among the 62 positive remote contacts we found :—

Type I.—	5 cases	= about	8 per cent. of the positives.	
.. II.	32 ..	= ..	51	..
.. III.—	1 ..	= ..	1	..
.. IV.	24 ..	= ..	38	..

It will be seen from these figures that, in spite of the fact that cases of Type I are twice as common as cases of Type II, in the throats of the contacts Type II is much more prevalent than Type I.

We can therefore only conclude that Type I cocci are more pathogenic than Type II.

9. *The length of Time during which a "Carrier" may be Negative and yet Relapse.*

This is a very important subject in relation to the treatment of carriers in the Services.

The object of the treatment of carriers is to remove the meningococci from the nasopharynx permanently, but since it is not practicable to prove the absence of the cocci over a long period of time, it is necessary to fix an arbitrary period which shall be assumed to establish a cure.

The most satisfactory interval has not yet to our knowledge been established. In the Army two negative examinations were taken to indicate a cure, but in the Navy at one time six negative examinations at weekly intervals were required. At the beginning of the season under discussion the number was reduced to four, and all our carriers have been subjected to this standard.

The following table (19) shows the number of men who relapsed after the attainment of different numbers of negative swabs, that is to say, the number of men who were not cured but who would have been assumed to be cured had their swabs been accepted as the index of cure.

The carriers referred to were all infected with pure "Gordon" types.

TABLE 19.

The number of Carriers who Relapsed after different numbers of Negative Tests.

No. of carriers examined, 375						
No. of carriers who relapsed at least once after 2 negative swabs, 137 = 36 per cent.						
No. of carriers who relapsed at least once after 3 negative swabs, 63 = 16 per cent.						
No. of carriers who relapsed at least once after				4 negative swabs	=	13
..	..	..	..	5	..	= 5
..	..	..	..	6	..	= 4
..	..	..	..	7	..	= 2
..	..	..	..	13	..	= 1

The men who relapsed after four or more negative swabs are not comparable with the others, because very few men were examined so often. Little or no statistical value can be extracted from these figures, but it is certainly remarkable that so many relapses occurred in so few cases.

From this table it is clear that if two negative swabs are taken as the index of cure, no less than 36 per cent. of the men will in fact not be cured, and will be returned to the community in the same condition as they were before they were isolated. It is also clear that under these conditions of "cure" a form of treatment may readily be supposed to have a value which in reality it does not possess.

Again, if three negative swabs are assumed to indicate cure, 16 per cent. of the carriers will be lost. The number of relapses after four negative swabs is not known, but should be about 10 per cent.

From these results it would appear that if two negative swabs are accepted any good which may have followed the isolation of the carriers must be largely neutralised, while if four negatives are taken the loss from this cause is considerably reduced.

The intermittent nature of the carrying of many of the men is also recognised by Bassett-Smith, Lynch and Mangham (*Journal of the Royal Naval Medical Service*, 1917.)

10. *The Treatment of Carriers*

In this section we are indebted to the co-operation of Surgeon P. B. Wallis, R.N., who was in charge of the carriers during their isolation.

Owing to the large number of carriers detected during the season it became necessary to attempt to sterilise the throats of these men, and, although from analogy with other diseases, the local application of antiseptics appeared likely to be unprofitable, it was thought desirable to give it a trial. If the antiseptic did not destroy the cocci in the throat it was possible that it might prevent the cross-infection of one man from another. Further, the use of inhaling rooms in the Army had been said to have given encouraging results.

In an experimental treatment of this sort there were three important matters to be considered:—

(*a*) The antiseptic to be used;
(*b*) The method of application;
(*c*) The index of cure.

The antiseptics used.—The antiseptics most thoroughly tested were Chloramine T and Acriflavine. Dakin's new Dichloramine compound came to hand too late in the season to undergo a satisfactory test.

Other antiseptics were boracic acid, carbolic acid, magnesium hypochlorite, formalin, potassium permanganate, guiacol and

several others. In addition to these we administered to a few men a *placebo* in the form of tablets of formalin.

The method of application.—Chloramine T was applied in two different ways :—

(*a*) In an inhaling chamber, the drug being dispersed as a fine cloud by a high pressure steam jet. This apparatus differed in design from that proposed by Col. Gordon for the Army, but no doubt gave similar results. A 5 per cent. solution of Chloramine T was used in the reservoir of the nebulizer : this strength was found to give as strong an atmosphere of chlorine as was pleasant. The room accommodated about ten men, and these remained therein for about fifteen minutes *per diem*. They were instructed to breathe strongly through the nose during this time, but there was no way to ensure that these orders were carried out, and in many cases they probably were not.

(*b*) In a nasopharyngeal spray. This was a glass hand spray made by one of us, the nozzle of which was readily slipped through the mouth into the nasopharynx. Two or three pumps were given with the bellows, and the Chloramine T (2 per cent.) thus came copiously into contact with the whole nasopharynx and often dripped from the anterior nares. This treatment was applied once a day.

Acriflavine (supplied to us by the Medical Research Committee) in a strength of 1 in 500, in salt solution, was applied daily with our nasopharyngeal spray.

The other antiseptics mentioned were used in the earlier stages of the investigation. They were all applied with Parke Davis & Co.'s "Glaseptic" nasal spray, until the drug could be felt in the nasopharynx. The strength of boracic acid was one drachm to the pint, of carbolic 1 in 200, of formalin 1 in 200, and of potassium permanganate 1 in 1,000.

The index of cure.—The apparent value of these antiseptic treatments depends very largely upon what end it is proposed to achieve and the exact manner in which the process is carried out. In general, the technique is to apply the treatment until swabs taken from the nasopharynx fail to reveal the meningococcus. The man is then looked upon as cured. There are, however, a number of fallacies which must be avoided.

(*a*) The treatment must not be carried on continuously during the whole period of quarantine for two reasons. First, the treatment if applied on the day that the swab is taken will directly vitiate the result. We have, therefore, always allowed twenty-four hours to elapse after treatment before the swab is taken.

Secondly, the treatment if applied continuously will readily diminish the number of meningococci or reduce their vitality so that they will not grow in culture, but when treatment is stopped they will frequently reappear again. It is therefore

essential not to apply treatment continuously, but to give the man a chance of relapsing before he is said to be cured.

In practice the routine has been as follows :—

(1) Upon receipt, a positive carrier is treated once a day until his next swab is due, that is to say, until six days have elapsed since the first swab. In practice this is usually one or two days treatment.

(2) Treatment is stopped twenty four hours before the swab is taken.

(3) It is continued after the swab is taken until the report is received.

(4) If this is negative treatment is stopped, and if the man remains negative on weekly test, no further treatment is given.

(5) If the report is positive, treatment is continued until the next swab is due. More recently in order to give the "positives" a greater degree of treatment, we have swabbed them while positive every fourteen days instead of every week. On a negative swab being obtained, however, we reverted to the weekly tests.

(*b*) A certain period of time must be allowed to elapse after a negative swab is obtained before a man is said to be cured, in order that the permanency of the cure may be established.

It is customary for a certain number of negative swabs at fixed intervals of time to be required before a man in the Services is allowed out of quarantine, and in the previous section we have shown that two negative swabs as commonly suggested is inadequate, while the four negative swabs as practised in the Navy during the past season is much more satisfactory.

In all our cases, therefore, the index of cure has been four consecutive negative swabs, taken at weekly intervals. During the whole of this time no treatment has been applied in order that every opportunity for early relapse might be present.

The results of treatment. Owing to the relatively small number of carriers, and to the fact that at first the treatment was often changed, the estimation of the value of these different methods is difficult. On examining the figures, however, it is soon found that there is another factor which enormously increases the difficulty, namely, that one third of the men become cured immediately upon entry, *whatever the treatment applied to them may be.*

Thus of 375 carriers of pure "Gordon" types, 124 registered their four consecutive negative tests immediately upon entry into the isolation camp. The treatment applied to these men was practically *nil*, since by the time the "doubtful" colonies had been proved to be positive and the man had been removed to the isolation camp, the greater part of the week had passed, and only one or, at the most, two days treatment remained before it had to be stopped preparatory to the next swab. When it

is remembered that some of the methods of treatment were obviously futile, it appears justifiable to us to regard the effect of treatment as *nil*, and to assume that these men cleared up spontaneously.

Since, then, one-third of the men are cured spontaneously, a drug must be very decisive in results before its curative action is very obvious.

The effect of the antiseptics has been estimated in two ways—

(1) By calculating the ratio of cures to the number of men treated by each antiseptic;

(2) By counting the number of men who obtained 4, 3, 2, 1 or no "negatives" *immediately* upon starting upon a particular treatment.

TABLE 20.

The Cures effected by Various Treatments.

Treatment.	No. Treated.	No. Cured.	Percentage Cured.
Chloramine T (in inhaling room)	85	43	50
Chloramine T (in spray)	96	60	62
Acriflavine	101	59	58
Boracic	50	29	58
Carbolic	64	30	46
Magn. hypochlor. ..	59	28	47
Formalin	65	29	44
Pot. permang.	63	30	47
Guaicol	35	17	50
Formamint	14	5	35
Average	632	330	52

(The cure is credited to that treatment under which the man was last.)

TABLE 21.

The "Immediate Negatives" obtained by Various Treatments.

Treatment.	No. Treated.	"Immediate Negatives."				
		4	3	2	1	0
Chloramine T (in inhaling room)	91	38	2	15	4	32
Chloramine T (in spray)	99	40	2	13	10	34
Acriflavine	101	51	11	9	26	4
Boracic	31	22	0	7	1	1
Carbolic	54	27	0	8	5	14
Magn. hypochlor ...	52	25	0	5	8	14
Formalin	55	22	0	11	6	16
Pot. permang ...	47	17	0	5	5	20
Guaicol	26	8	0	4	0	14
Formamint	15	0	0	3	0	6

Table 20 shows that about 50 per cent. of the men treated by any method were cured. Any variation in the percentage is not greater than might be produced by chance, and has no significance.

Table 21 shows that with each form of treatment 40–50 per cent. of the men are cured immediately; with boracic acid alone the figure is higher, but here the factor of error due to small numbers comes in acutely. This percentage (40–50) corresponds roughly to that given by all treatments together (33), which, as has been explained, may be assumed to be no treatment. The difference between the 33 per cent. of no treatment and the 40–50 per cent. of treatment is due not to the efficacy of treatment but to the fact that the two figures are calculated from two different series of men. The 33 per cent. relates to carriers of meningococci which agglutinate with monovalent sera, while the 40–50 per cent. refers to a series which includes, in addition, a number of carriers of cocci which agglutinate feebly or not at all with monovalent sera. These latter often fail to agglutinate, and therefore these carriers are more easily "cured."

It is clear that the therapeutic effect of none of these antiseptics is sufficiently great to class one as better than another.

On examining the figures of those men who remained positive after treatment, it is again observed that the results are fairly similar; about one third of the men failed to obtain a negative immediately after treatment. Acriflavine and boracic are exceptions to this rule; the former showed only four positive in 101 after treatment, and the latter one positive out of 31. In the case of acriflavine these positives have passed into the group of "one immediate negative," and there is some evidence that acriflavine actually does produce a transient inhibition of the bacteria.

Looking at the results as a whole we conclude that one third of the men recover spontaneously, and that none of the methods of treatment tested have any conspicuous merit, nor has one any obvious advantage over another. This result is what might be expected from analogy with work on diphtheria carriers.

We are much indebted to Dr. John Brownlee, statistician to the Medical Research Committee, for opinions upon figures submitted to him.

11. *The occurrence of Cerebro-Spinal Fever or Meningitis among Carriers.*

It has long been recognised that carriers do not often develop cerebro-spinal fever.

Flack, in his report on the London District (Medical Research Committee Spec. Rep. Series, No. 3, p. 59), states that 185 men were treated as carriers, and that 4 developed cerebro-spinal fever. If, however, the evidence adduced by Captain Flack is

critically examined, it cannot be certain that all of his cases are proved instances of this phenomenon.

We have had a larger number of carriers under observation during the past season ; in all, 485. None of these men developed cerebro spinal fever, although all carried meningococci in their throats, some for days and some for months.

Flack (Medical Research Committee Spec. Rep. Series, No. 3, p. 61) also describes a condition of "Meningismus" to exist among carriers. These men complain of severe headache, pains in the back of the neck, and back also. A slight "Kernig" may be present. Lumbar puncture does not appear to have been performed usually, and when performed was negative. A swab from the nasopharynx however, was positive. The cases may recover overnight. It is apparently suggested that these cases are slight, and transient attacks of cerebral meningitis or irritation due to meningococci in the throat of carriers. As Flack admits, however, men are found with similar symptoms without meningococci in the throat, and these are of an "influenzal" nature.

This suggestion of mild, transient meningococcal infections is one of importance. We may, however, state that not one of our 485 carriers exhibited symptoms of this sort. If they had they would have been transferred immediately to the fever hospital and lumbar punctured. If they had shown no evidence of meningitis we should have been unable to diagnose "meningococcal meningismus." The presence of meningococci in the throat is not, in our opinion, sufficient to found a diagnosis of meningococcal meningitis upon, as opposed to "influenza," especially when there is no evidence of meningitis in the cerebro spinal fluid. We have actually found, at one season, 7 per cent. of normal persons to be harbouring meningococci.

On the whole, we are not prepared to admit that carriers are susceptible to cerebro spinal meningitis or "meningism" except on very rare occasions. In order to make our standpoint clearer we must point out that there is often some slight confusion in the use of the word "carrier" in this connection. If a man is thought to be suffering from cerebro spinal fever or meningism, and his throat is found to be positive, it does not follow that his throat was positive *before* the onset of the suspicious symptoms, and therefore it does not follow that he was a carrier. The meningococci may merely be associated with the onset of the disease. As we have shown, the case of cerebro spinal fever often becomes a carrier, but before the onset is not a carrier.

Therefore, when endeavouring to establish the occurrence of disease among carriers, it is necessary to confine oneself to men who have actually been proved to be carriers before the question of disease arises. The practical point is whether any of a large number of men isolated as carriers will get cerebro-spinal fever, and it is clear that none will, except perhaps as a rare exception.

12. *The Relation of the case of Cerebro-Spinal Fever to the Positive Contacts and to other cases*

One of the problems of practical importance in connection with cerebro-spinal fever is the question whether the case has infected those of his contacts who are subsequently found to be positive, or whether the case has been infected by one of a collection of already positive contacts.

There appear to be two fundamentally different views upon this subject. According to the first, the case is essentially a carrier and is responsible for propagating the disease by spraying cocci from his throat. The positive contacts have derived their infection from the case and may develop the disease. According to the second view the case is not a carrier in the ordinary sense of the word, and is not specially responsible for the propagation of the disease. The positive contacts may have derived their infection from another carrier, and the case is infected by one or more of these contacts.

The correct elucidation of this problem has a bearing upon cerebro-spinal fever administration in the Navy. The first view would suggest that if, for instance, a case is brought into a general ward before removal to an isolation hospital, not only the original messmates of the case should be swabbed, but also the patients in the ward, *to see if the case has infected anyone*. On the other hand, the second view would not entail the swabbing of the ward, because the object in view is to *find the carrier who infected the case*.

This question is very difficult to settle by direct evidence, but indirectly the following is important

(1) According to the first view the case must be a carrier before the onset of the disease, but we have already shown that the observed facts are contrary to this being so. Twenty-six of our cases had been examined at short or long periods before the onset, and none of these were then found to be carriers. (p. 33)

(2) If cases are carriers before the onset, it should be common for demonstrated carriers to develop cerebro-spinal fever. This also we have shown not to be the case.

We have had 485 carriers under observation, and none of these have developed cerebro-spinal fever. (p. 64)

It is therefore our view that cases of cerebro-spinal fever are not carriers before the onset, and from this it follows that they cannot have infected the contacts who are found positive at the onset. On these grounds it appears most probable to us that the case has been infected by carriers who were in contact before the onset of symptoms.

With regard to the connection between one case and another, it is possible that one case may derive the infection from a previous case. The former would then simply act as a "carrier" among the contacts of the second. Such a mode of infection might occur among attendants, but within our experience never has

occurred. In a barracks, of course, it is hardly possible because the case is immediately removed from the contacts.

The chief objection to the theory of propagation of the disease by a case lies in the fact that the case is as often as not free from cocci in the throat a short time after onset, and, further, is seldom at any time so heavily infected or so persistent as an ordinary carrier.

We have endeavoured to obtain direct evidence on these matters, but it is clearly very difficult to do so.

We have analysed associated cases in order to show the relation between the cases and contacts, and also between the cases themselves, with a view to finding evidence of infection from case to case or from contacts to case.

Chart 5 indicates the state of one of the rooms in the Royal Naval Barracks, Portsmouth, in which seven cases of cerebro-spinal meningitis occurred in 3½ months. It might be expected that evidence of infection from case to case would be available in such a series.

It will be observed that the first case occurred in Mess 5, and was removed before the next case in Mess 4 entered the room. Similarly, this case had gone before the first case in Mess 3 occurred, and this case in Mess 3 before the next case in Mess 1. None of these attacks can therefore be connected. A man entered Mess 3 on March 6th, a day before the man in Mess 1 developed cerebro-spinal meningitis; several weeks later he also developed cerebro-spinal meningitis, but any connection between these two cases is grossly improbable. The case in Mess 3, which developed on March 12th, did not enter the room until the man in Mess 1 had gone, and the case of April 2nd in Mess 3 did not enter until the case of March 12th had gone. We now come to the last case of April 18th; this man was a close contact of the case of April 2nd, and developed an infection of the same type. If, however, the first case had infected the second, the incubation period would have been at least sixteen days—an extremely long one. On the other hand there is ample evidence of contact of the second case with two chronic carriers of the same type of coccus in the same mess.

It will be understood that the members of each mess can have free intercourse in one room, and therefore it is quite possible for the Type I case of February 19th, in Mess 3, to have been infected by the Type I carrier in Mess 2. Generally, when Types II or IV are involved, there are so many carriers of these types that it is impossible to suggest which of them are responsible for the infection of the case.

Chart 6 illustrates two cases associated with the relatively rare Type I carrier. They occurred in one mess on consecutive days. Since, however, the first case had only been in the mess for two days, and he was then negative, it is almost impossible to imagine that he could have directly infected the second.

Most of the possible contacts had nothing to do with the infection being of a different type, but there were two contacts of the same type (Case I). The first case was closely associated with another carrier in the previous mess who was not of course taken as a contact. He was also associated with the carrier who entered the mess on 27th February. The third carrier can hardly have been responsible. With regard to the second case, this was not in contact with the carrier in the "new entry" mess, and was only associated with the carrier entering the mess on February 27th. The carrier in the "new entry" mess may have infected the first case and the contact who entered the mess on March 3rd, while the other contact may have infected the second case. On the whole, however, it appears more probable that the man who infected the second also infected the first.

This chart also illustrates the manner in which carriers may rapidly accumulate in a mess after they have been passed in as free from infection, and, further, how there may be an accumulation of carriers of an entirely different type to that of the case which subsequently develop.

V. The Epidemiology of Cerebro-Spinal Fever.

1. *The Meningococcus as a Group of Gram Negative Cocci.*

From the various observations which we have made it would appear to be justifiable to speak of a "meningococcus group of bacteria." All cocci in this group have to a variable degree the morphological appearance which may be described as "typical." They are of course all Gram negative, all grow with a certain type of variety which also is variable to a certain degree, and all ferment glucose and maltose but not saccharose.

It will be seen (p. 42) that some cocci which qualify in all the above particulars are not agglutinated by any meningococcus serum, even the polyvalent Flexner serum. Others, again, are agglutinated by Flexner's serum but not by Gordon's sera, and we have shown (p. 39) that roughly half of such strains do not absorb Gordon's types, while about half do. Other cocci again, agglutinate with Gordon's type sera.

We have therefore a series of cocci of the same general characteristics which range from agglutinable to agglutinable by polyvalent serum and agglutinable by univalent serum. This series may be followed continuously from the agglutinable types to Gordon's Type IV, since (p. 39) all of those "Flexner" types which do not agglutinate with Gordon's serum but absorb agglutinin for his types really belong to the Group IV II. It is probable that Type IV is the most specialised member of this series, while Type II is more closely related to the "Flexner absorbing" type. This assumption rests upon the fact that Type IV cocci produce more strictly univalent anti-serum (p. 46), while Type II anti-sera show relationships with other groups. Further, Type IV cocci show evidences of being more pathogenic

in the throat than Type II cocci, that is to say they are capable of replacing Type II in the throat (p. 54) and maintain themselves for a longer time in the throat (p. 52). There is also evidence that Type IV is actually more pathogenic than Type II in the sense that it is more liable to produce cerebro-spinal fever (p. 57).

This meningococcus series may therefore be represented schematically as follows:

Meningococcus Group

(Gram negative diplo-cocci fermenting glucose and maltose, but not saccharose.)

Inagglutinable types.

Flexner non-absorbing type.

Flexner absorbing types.

Gordon's Type II.

Gordon's Type IV.

Of these the last two are known to be capable of producing cerebro-spinal fever, and may therefore be called pathogenic. The Flexner absorbing types may be included in the same category although within our experience there has been no case of meningitis due to a *permanent* Flexner type. Such strains isolated from the cerebro-spinal fluid have all developed some reaction to Gordon's sera after several subcultures. The first two members of the group are merely saprophytic and there is no evidence that they can produce cerebro-spinal fever. Whether they are capable of altering their characters in a short time so as to assume a pathogenic role is, of course, not known but may be considered improbable.

It will be observed that Types I and III find no place in this scheme. Since none of the Flexner strains which are the link between Gordon's types and agglutinable varieties belong to Types I or III it must be assumed that this group is somewhat isolated.

Type I and III cocci in the throat are much less common than Type IV and II cocci and therefore it is possible that the transitional forms between the Group I, III and agglutinable types are too few to detect. It might, however, be expected that Flexner's serum would have detected such transitional forms if they existed, but this was not the case.

From the group affinities between these cocci (pp. 14 & 15) it is clear that there is little direct relationship between Type I and Type IV, but that Types II and III are directly and mutually related, and, further, act as a link between Types I and IV. Type II serum has some agglutinating action on all cocci, and similarly Type III serum affects all cocci to some extent. How-

Type II is related directly with Type I and also indirectly, through Type III while Type III is related directly, with Type IV, and indirectly through Type II

The following diagram illustrates graphically the relationship between these types

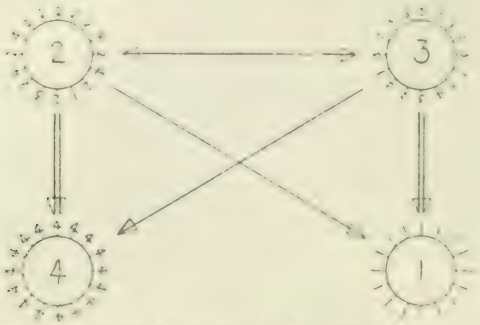


Diagram showing the inter-relationship between the four types of meningococci and their contagious characteristics

On the whole, we consider it to be probable that a series from non pathogenic to Type I exists in the same way that it exists up to Type IV, and that these series run parallel to each other and are connected throughout by common characteristics. It appears to us to be less probable that the Type IV II group, and the Type I III group, spring from a common "Flexner" stock.

Our investigations show that the pathogenic importance of these two groups of meningococci is widely different. Group I III shows itself to be a distinctly more pathogenic group than Group IV II (p. 57), while we have evidence to show that Group IV. II is more prone to lead a saprophytic existence in the nasopharynx (p. 52).

2 *The Meningococcus as a normal Inhabitant of the Throat, subject to seasonal waves of activity.*

From Chart 3 which is in fact an actual census of the proportion of the population which harboured meningococci in the throat throughout the whole season 1916-17, it is seen that on several occasions we found as many as 6 to 7 per cent infected. This, however, was only during the winter and spring: through out the summer the numbers fell away to a much smaller proportion.

It must, however, be understood that this figure only represents the number of epidemic meningococci actually isolated upon a single examination, and we have shown (p. 48) that 50 per cent.

more may be found by a second examination. We have no doubt that still more would be found on further examinations, and therefore we can assume that were this factor only eliminated the percentage of persons demonstrated to have been infected would have been more like twelve.

These remarks apply only to the "epidemic strains" and we have, of course, no figures on which to estimate the prevalence of the non pathogenic members of the meningococcus group. We find that the "positives" are at most only one half of the colonies selected by us as "probable," and therefore the meningococcus group, pathogenic and non-pathogenic, may be looked upon as having been very widely disseminated during this winter. Possibly more than 25 per cent. of the adult male population were infected.

This high proportion of infected persons fell rapidly during the summer, but the cocci were never at any time entirely absent. There was always a small persistent rate of carriers.

The rise during the winter and spring may be looked upon as a pathological increase in this persistent rate, and the transient nature of many of the infections (p. 52) appears to indicate that these are fleeting manifestations of an actual epidemic from throat to throat.

If this seasonal outbreak is studied in greater detail (Chart 4), it is seen that the great bulk of the epidemic and sporadic carriers were due to Types IV and II cocci. Types I and III cocci being much less common, only appeared in epidemic numbers during the winter, and faded away during the spring. In the summer the number persisting was so small as to escape detection.

3. *The relation between the Seasonal Outbreak of Throat Infections and the Outbreak of Cerebro-Spinal Fever.*

If Charts 1 and 3 be compared it is seen that there is a close relationship between the frequency of meningococci in the throats of the general population and the incidence of cerebro-spinal fever. Both are high in winter and spring and low in summer.

Charts 2 and 4 indicate the relation of the types in throat and case to each other. The pathogenic Group I. III is scarce in the throat after February, and practically at the same time there is a falling off in the number of cases due to Types I and III. Thereafter this group is found in the throat and case occasionally up to July.

The less pathogenic Group IV. II persists in the throat much longer than Group I. III as might be expected. It also persists for a considerable time after the last case has been recorded, and similarly is present before the first case due to Group IV. II occurred.

This evidence appears undoubtedly to favour the view that the cases of cerebro-spinal fever occur as the result of an increased incidence of meningococci in the throats of the general population.

It will be observed that there is some indication of a small secondary rise in the case curve during May and June (p. 30), and a similar elevation is seen in the throat curve (p. 40). The cases, however, are relatively Group I. III. while the throat swabs are almost exclusively Group IV. II. This, however, does not, in our opinion, invalidate the argument that these cases were due to a secondary rise in the number of Group I. III. cocci in throat. The conditions which determined the rise in Group IV. II. cocci would also determine a rise in Group I. III. cocci, for these cocci being always few in number the outbreak may have escaped detection.

4. *The mechanism of Infection of the Case from a high throat rate in the population.*

The actual stages by which an individual contracts cerebro-spinal fever as the result of a high ratio of meningococci in the throats of the community is not exactly known.

There are several contingencies :—

(a) The "positive" members of the community may actually develop an infection of their cerebro-spinal system as the result of some alteration in resistance.

(b) The "negative" members of the community may become infected by an "overdose" strain derived directly from a case of the disease.

(c) A "negative" person may acquire an infection from one of the positive members of the community, and instead of "carrying" he may succumb to cerebro-spinal fever.

(a) We have already shown (p. 34) that among the large number of "positives" under our observation no case of cerebro-spinal fever occurred. Such an event, if it occurs at all, must be very rare. In our opinion many of the alleged cases of cerebro-spinal fever which have been reported to have occurred among "carriers" are incorrectly so described owing to the application of an incorrect meaning to the word "carrier."

Further, if "carriers" developed cerebro-spinal fever it should be possible to show that some cases of fever had "positive" throats before the onset, but this we have demonstrated not to be the case (p. 33).

On these grounds we do not consider that the fact of a pre-existing meningococcal infection of the throat appreciably predisposes the individual to cerebro-spinal fever.

(b) It is probably a fact that at the time of the onset and for a short period afterwards cases of cerebro-spinal fever "carry" the meningococci in the nasopharynx. They may, therefore, pass the infection to another person.

Our results (p. 33), however, indicate that the case very rapidly loses its infectivity, and although a few may "carry" persistently, they are seldom infected to the same degree as the

ordinary carrier. On these grounds it would appear that a case is more unlikely to propagate an infection than an ordinary carrier.

Direct evidence of infection of an individual from a case is entirely absent in our experience. No person who has had to do with cerebro-spinal fever patients in Haslar has for two years within our knowledge, or ever, according to report, developed cerebro-spinal fever. It is, of course, well known that cerebro-spinal fever patients are nursed in general wards in many hospitals. Nevertheless the danger of cerebro-spinal fever is a deep-rooted concept in some quarters.

We have made every effort to establish the line of infection in promising cases. For instance, when several men are attacked in one room, it should be possible to make out a case to implicate an individual with some degree of probability.

Thus we have analysed the seven cases which occurred in one room at the Royal Naval Barracks, Portsmouth (p. 67). Only one of these men could have been infected by a preceding case because it was found that none of the others were in the room at the same time. In the one solitary instance the evidence was strongly against an infection from case to case.

We have also analysed the circumstances surrounding an outbreak of two cases on consecutive days, which occurred in one mess of twenty-four men in the barracks (p. 67). In this case also, although the history would appear to indicate strongly an infection from one man to another, the evidence does not support this view.

We are therefore forced to conclude that the declared case has very little to do with the propagation of cerebro-spinal fever.

(*c*)—The transient nature of a large number of the naso-pharyngeal infections is evidence that during the "season" there is a continual dissemination of cocci and transient infection of "negatives." In the vast majority of cases this infection is confined to the nasopharynx by some unknown protective mechanism, while in a very small number the infection is not so confined but becomes general. The interval between infection and generalisation must be very short, since we have examined men as little as two days before the onset and found their throats negative (p. 33).

We have little doubt that for practical purposes this is the only method of spread of cerebro-spinal fever which need be considered. During the course of an epidemic spread of transient throat infections an occasional individual is found who succumbs to cerebro-spinal fever. The disease is, therefore, more or less an accidental bye-product of the throat epidemic.

This infection by healthy "carriers" is practically impossible to *prove*. It will be understood that when a case of cerebro-spinal fever occurs, the contacts are "swabbed" and some are found to be positive and others negative. It appears to be often

. . . ssed that the positive contacts have been infected by the case, since it may be demonstrated that the contacts have a considerably greater number of positives (10 per cent.) than a collection of non-contacts (3·4 per cent.).

To us, however, it seems almost certain that the positive contacts of a case have not been infected by the case if for no other reason, because before the onset of the disease the case is "negative" and since the case is removed immediately there is very little opportunity for infection to occur. The contacts are generally swabbed almost immediately and thus if an infection is found it could hardly have had time to develop from the case.

There are several observations which bear upon this question.

(1) The high rate among close contacts (10 per cent.) cannot be due to infection from the case, because (p. 49) over half of the "positives" among a collection of close contacts are infected with a coccus which is of a different type to that infecting the case.

(2) The rate among remote contacts (7·6 per cent.) is also much higher than among non-contacts, but it may be shown (p. 49) that most of these could not have been infected by the case since they were of a different type. The small remainder who happened to be infected with the same type of coccus as the case need not have derived the cocci from the case. Some of them at least must merely belong to the normal carrier population. It thus follows that practically all of the positives among remote contacts (7·6 per cent.) must be unconnected directly with the case and must represent the *pre-existing* rate for the community in which the case occurs.

(3) The only difference between the close contact and the remote contact is (p. 49) that 5 per cent. of the former, as opposed to 2·1 per cent. of the latter, carry the same type of coccus as the case. Those nasopharyngeal cocci which are different from the cocci of the case are exactly the same in close and remote contacts as would be expected.

The difference between 5 per cent. and 2·1 per cent. is extremely slight when the closeness of contact in the case of our close contacts is remembered, but, nevertheless, it is probable that in the immediate vicinity of the case there is a slight pre-existing concentration of cocci of the same type as those which have infected the case.

These data suggest to us that a case occurs because in its vicinity there is a fairly high rate of positive carriers, while in its immediate vicinity the rate is still slightly higher. To establish an infection therefore it is necessary to have conditions of ventilation, possibly of weather or accident which entail a high carrier rate in a community. In addition to this it is necessary to have a susceptible individual, and usually an exposure of this individual to a slightly greater concentration of infection. Given an infection under these conditions the cocci very rapidly invade the blood stream and localise in the cerebro-spinal system.

Charts 5 and 6 illustrate this view as far as it is possible to illustrate it.

VI.—Technique.

1. *The Examination of the Cerebro-Spinal Fluid*

The examination of the cerebro-spinal fluid should be carried out soon after withdrawal. Our technique has been as follows:—

The fluid is removed to the laboratory and examined within the hour. Part of the specimen is centrifuged and from the deposit films are made and an Hb. serum agar tube inoculated. Another tube is flowed over with the uncentrifuged deposit, and the excess is poured away. The remaining fluid is incubated with the culture tubes.

We find that one of these latter methods will sometimes give growth when the first will not.

In twenty-four hours a rich growth has developed in many cases, while in others only two or three colonies. Apart from differences in the abundance of cocci in different cases, scanty growth seems to be sometimes due to the cocci being for the most part dead. In the negative cases new films and cultures should be made from the incubated cerebro spinal fluid.

From the first pure culture obtained a "stab" is made into Hb. serum agar, and this is closed with a sublimated rubber cap and kept as a stock at 37°C.

It is not necessary for the routine diagnosis of meningococcal meningitis to identify the cocci more closely, but, if desired, the culture may be tested at once as described later with various agglutinating sera.

2. *The Examination for Carriers.*

In making cultures from the nasopharynx we have used tubes of Hb. serum agar entirely, instead of plates. In addition to the economy in medium, tubes may, if suitably capped, be stored for weeks in perfect condition for immediate use. It has been our habit to keep a reserve of 200 tubes in this manner.

In making the culture the nasopharynx is swabbed in the usual way with West's tube. The wire is entirely withdrawn, and the top of the swab is dipped into the drop of condensation water in the tube. The wool plug is then replaced, and the tubes collected in baskets until the batch of men is finished. The condensation water is then guided over the surface of the slope with a platinum wire; the tubes are capped and incubated for twenty-four hours. When examined next day an even and not too copious growth is found with well isolated colonies. The meningococcus colonies have a characteristic greyish opalescent appearance, and are about 2 mm. in diameter. With practice they are easily recognised. If none are seen, the case is reported "negative"; if likely colonies are present the case is reported "doubtful". The colony is picked off and subcultured

upon the serum agar and twenty four hours being a sufficient growth is ready for agglutination tests.

We rely upon agglutination tests entirely for diagnosis. With experience we find it unnecessary to make a microscopic examination, while bacteriological tests have been abandoned entirely.

3. Culture Media

In our investigations the medium used for the growth of the organism has been serum agar, containing a small quantity of boiled blood (Hb. serum agar).

(a) *The preparation of the sterile serum.*—The serum is obtained from the slaughter house, as follows:

(1) Collect the blood from the ox in large enamelled (not basic) wash basins) with some form of cover.

(2) Allow to stand for a few hours till clotted.

(3) Cut the clot into segments to facilitate contraction.

(4) After two days, syphon off the serum into flasks and convey to the laboratory.

The serum thus obtained contains a varying amount of red cells and before one proceeds with sterilisation these are allowed to settle. Ox serum has always been used, and in that the red cells settle down much more slowly than with horse serum. It has been found that the best method of obtaining a rapid sedimentation of the red cells is to place the serum in flat trays and not in cylindrical jars as is usually done.

(1) Place the serum in flat enamelled iron photographic dishes 15 in. by 12 in. about 2 in. deep covered with sheets of glass.

(2) Place in the ice chest for two or three days.

The red cells will now be found to be in a compact film on the bottom of the dish.

(3) Syphon off the clear serum into glass bottles of convenient size with well fitting ground in stoppers oiled to prevent sticking.

All the above apparatus is sterilised to reduce contamination as much as possible.

The sterilisation of the serum is carried out as follows (P. Fildes, *Lancet*, 1917, March 31st):

(1) Add chloroform to each bottle in the proportion of 1 of chloroform to 200-250 of serum.

(2) Shake thoroughly.

(3) Place in the incubator at 37° C.

(4) Leave twenty four hours, shaking occasionally.

(5) Remove samples from each bottle and test sterility.

(6) Replace in the incubator for a further period of twenty four hours any bottles showing contamination and retest for sterility.

By this method it is possible to obtain large quantities of absolutely clear sterile serum, for, although the process will not sterilise grossly spore-contaminated serum, it is found perfectly adequate in dealing with the moderate contamination met with in serum collected in the manner outlined above. It has very occasionally happened that the serum develops an opacity during sterilisation, and this appears to be due to an excess of lactic-coagulating soluble substance in the serum, forming an emulsion with the chloroform. When this occurs it is better to destroy the serum away if it becomes too opaque. The stock bottles should be allowed to stand without being disturbed to allow any light deposit to settle.

(b) The preparation of sterile laked blood.—(1) Collect the blood from the slaughtered ox into a large glass vessel.

(2) Defibrinate by whipping.

(3) Convey to the laboratory in flasks.

(4) Lake the blood by adding an equal quantity of sterile distilled water. Ox blood will lake fully in the presence of 0·5 per cent. sodium chloride, while the figure for man is usually about 0·3 per cent.

(5) Bottle and sterilise as with serum.

All glassware and apparatus being sterilised, this laked blood is practically sterile itself. It is desirable to carry out the process as aseptically as possible, because the blood cannot be incubated for more than twenty-four hours without destroying its transparency.

(c) Medium for throat cultures.—A two litre bottle of serum has added to it 5 per cent. of the laked blood. Allow this to mix by diffusion. Do not shake. The stopper is then removed and a distributing apparatus is inserted, which will allow the serum to be conveyed aseptically into the liquefied agar. The agar is made with sodium chloride and peptone water only. It contains 2·15 per cent. agar and is standardised to +10. We have used Morson's peptone exclusively. In practice, 700 c.c. to 1 litre are sterilised in pressure flasks. When melted for use, 100 c.c. of Hb serum is run in and the whole is distributed through a special hooded apparatus into tubes. When this tubing is carried out in a large (unsuitable) room the contaminations vary between none and 5 per cent. of the tubes, according to the season of the year. When set the tubes are stacked in the *horizontal* position in baskets, and incubated in the *horizontal* position for twenty-four hours. This will stick the serum agar to the tube, but will not dry it up.

It will be observed that the chloroform is not removed from the serum. There appears to be no necessity to do this.

This medium should be absolutely clear and show no trace of red colour. Care should be taken that the agar is not allowed to get too cold when mixed with cold serum. This is a cause of opacity and "sloppiness." The temperature should not fall below 55° C.

(d) Medium for general purposes.—For all purposes other than throat cultures we use Hb. serum agar containing twice as much serum, namely, 25 per cent.

The serum bottle, usually 200 c.c., has added to it 4 c.c. of the laked blood. We usually distribute this Hb. serum into small flasks in lots of 50 c.c. The agar is made 2½ per cent. and is put up in small flasks in lots of 150 c.c. The serum is poured into a flask of melted agar, and the whole is warmed up and poured by hand into the test tubes. In a suitable small room this may be done without contamination.

This medium contains 25 per cent. of serum and 1 part of *whole* ox blood in 400.

The tubes are always kept in the horizontal position to prevent them drying unevenly.

(e) *The value of hæmolysis in the medium.*—Towards the end of last year (1916) when using 25 per cent. serum without added blood, several samples of serum were met with which gave very poor, or, in some cases, no growth of the meningococcus on first subculture. We were compelled to use temporarily human blood agar, and for the sake of economy the amount of blood was continually reduced. We thus found that a very small quantity of blood is necessary to "stimulate" the meningococcus, in fact that laked blood added to serum agar in a strength of 1 in 1,000 was sufficient. In practice we use 1 in 400 of laked ox blood in the medium. This gives excellent results, producing a uniformly copious growth.

(f) *The percentage of serum in the medium.*—We have experimented with Hb. serum agar containing 5 per cent., 10 per cent., and 25 per cent. of serum.

Five per cent. serum gives, on the whole, markedly inferior results.

Ten per cent. gives fairly good growth of the meningococcus, and is found quite satisfactory for primary cultures from the nasopharynx. The organism appears to grow more readily in primary culture than in subcultures, being possibly activated by the presence of a certain amount of pharyngeal secretion.

Twenty-five per cent. gives uniformly copious growths, especially useful in the case of subcultures when suspensions for agglutination purposes are required. It is also used for primary cultures from the cerebro-spinal fluid, and for maintaining stock cultures.

(g) *Stab cultures.*—Stab cultures in Hb. serum agar are used. Special precautions against contamination by moulds especially are taken.

Technique used:—

(1) Pour tubes for stab culture.

(2) Burn the tops of the wool plugs thoroughly, and cap with well fitting rubber caps soaked for twenty-four hours in strong mercuric chloride solution and applied wet.

(3) Incubate twenty-four hours.
(4) Leave at room temperature for at least a week before using.
(5) Whenever opened re-apply caps freshly soaked in mercuric chloride solution, at the same time thoroughly burning plugs.

A supply of medium for stock cultures, tubed and capped in the above manner, may be kept for several months before use. They show no signs of deterioration or of drying up.

In these stab cultures the meningococcus will survive for two to three months.

(*b*) *Media for fermentation reactions.*—At the beginning of the work we used ordinary serum agar, containing 1 per cent. of the sugar and neutral red as an indicator. Afterwards, however, we used a liquid medium consisting of plain peptone water enriched with 1 per cent. of serum. In this we used litmus as the indicator.

This latter medium is much better than the solid medium, and gives sharper results. It appears to be important to reduce the amount of serum to a minimum in order to limit the formation of alkali by the ferments of the cocci.

4. *Agglutination Reactions.*

(*a*) *Sera employed.*—At the end of last year Lieut.-Colonel M. H. Gordon kindly supplied us with samples of agglutinating sera for his four types of meningococci. By means of these we were able to identify the strains which had been isolated by us from the cerebro-spinal fluid at that time. Cultures of each of the four types were thus obtained and further supplies of serum maintained by immunising rabbits against these.

In addition to monovalent sera for each of Gordon's four types we used a polyvalent serum—Flexner's "antimeningitis serum," made by the Rockefeller Institute.

Each of these five sera was diluted to 1 in 100 with tap-water carbolic saline ($\frac{1}{2}$ per cent. carbolic), sufficient to last two or three weeks being diluted at a time and kept in the ice chest.

(*b*) *Preparation of agglutinatory serum.*—The technique which we adopted for immunising rabbits was at first founded upon that suggested by Hine (Medical Research Committee Spec. Rep. Series, No. 3, p. 99). We administered to the rabbits, intravenously, two doses of 500 million cocci at an interval of one hour, and on the sixth day following another dose of 3,000 million. The serum was tested on the eighth day, and if satisfactory the animal killed on the ninth.

In our limited experience (we have used only seventeen rabbits) this method was satisfactory when dealing with Types I and III, but with the others we were not fortunate. We have therefore tended to use larger doses and have sometimes repeated them more often, and none of our animals have died. In

particular, with Type II. the production of a good serum seems to depend largely on chance, but with the larger repeated doses it has appeared to be that the results are more regular.

Our guinea-pigs are seen generally as follows :—

Rabbits have been used which weigh between 5½ and 6 kgs. grms. On the first day they have received 4,000,000 bacilli each. On the sixth day, 10,000 each, it seems.

Two days before the serum has been tested, and if satisfactory the animals bled from the heart. If not, 10,000 million more have been injected at intervals of six days. In most cases it does not appear to be possible to procure sera of a higher titre than 1 in 800, however many doses are given. We have obtained the serum by sterilizing the animals and removing the skin from the neck. The throat is then cut over a dish, and the blood collected into sterile tubes. It is allowed to clot, and next day the serum is removed and cleared in the centrifuge. It is put up in 10 c.c. bottles with rubber stoppers, and sterilized with ½ per cent. chloroform at 37° C. for twenty-four hours.

(c) Preparation of suspensions for agglutinating.—The twenty-four hours growth in 20 tubes of 2½ per cent. BH serum agar is washed off the slope by agitation with saline solution. This suspension is then poured into a test tube and heated to 65° C. for half an hour. The tube is now allowed to stand for several hours if the suspension is not homogeneous to deposit the flocculi and then it is diluted with tap water carbolic (½ per cent.) saline to a standard opacity.

Our standard opacity has been a suspension of freshly precipitated barium sulphate, four times as thick as that required for agglutinating purposes.

The suspension to be standardised is put into a test tube of similar dimensions to our standard tube, and diluted until the image of a small flame is just visible at the same distance from the flame, as in the case of the standard tube.

This thickness of suspension is used by us for absorption tests. It is diluted four times for agglutinations.

(d) Performance of the test.—Small agglutination tubes (½ in. by 2 in.) are used, six being required for each case. They are held in a wooden rack consisting of a solid piece of wood, 9 in. by 6½ in. by 1 in. thick, bored with 144 holes. 0·2 c.c. of each of the five sera, and the same quantity of saline as a control, is measured into the tubes, and then to each 0·2 c.c. of the diluted suspension. The dilution of serum is thus 1 in 200. The rack is allowed to stand at room temperature for one hour, and is then placed in a hot air oven at 55° C. for twenty four hours. Many cocci agglutinate before the full period is complete, but on the other hand, some require even longer than this. The long period of incubation necessitates steps to be taken to prevent evaporation. This is a matter of the utmost importance, as shown on p. 10. We cover up the tubes with a pad of wet cotton wool enclosed in piconet.

(e) *Reading the results.* The presence of agglutination is judged by comparing the opacity of the suspension in each of the six tubes, as well as by the presence of flocculi in the tubes. The examination should always be carried out with the aid of a hand lens. Any definite agglutination which can be detected with a hand lens may be taken as positive, except in the case of Flexner's serum. With this serum we do not accept as positive unless agglutination is complete.

Care should always be taken that a true agglutination is being dealt with, and that the control is quite negative. It is of course common to meet with gram negative cocci which form poor suspensions, and these are apt to be misleading unless care is exercised.

Using the sera in the strength indicated, the meningococcus usually agglutinates completely with one Gordon serum and Flexner's serum, and not at all with the others. Sometimes two Gordon sera are found to have caused agglutination, and in such a case it will be a Type IV coccus agglutinating with Type IV and Type II serum, or a Type I coccus agglutinating with Type I and Type III serum. It is extremely rare to find any other combination.

(f) *The effect of age on the suspensions.*—There is no doubt that the practice of allowing the suspensions diluted with carbolic saline to stand for twenty four hours increases the agglutinability of the cocci. If time permits, this technique should be adopted. The specific agglutinability increases continuously to a slight extent for a considerable time.

Suspensions prepared in the manner indicated appear to maintain their characters unimpaired for at least nine months.

(g) *The effect of heat and carbolic upon the agglutination titre of the serum.* On several occasions when we were using a water bath at 55° C. instead of an air oven at 55° C. we observed that the agglutinating action of Flexner's serum was practically destroyed.

This led us to investigate the effect of heat upon the agglutinating sera.

We found that the Type I sera (rabbit) were unaffected by heating at 55° C. for several hours in a water bath, either when diluted with carbolic or with saline solution. Flexner's serum however, was uninfluenced when heated for three hours at 55° C. diluted with saline solution, but entirely destroyed in one hour under the same conditions diluted with carbolic.

This susceptibility of Flexner's serum to heat makes the use of a water bath impossible for agglutinations, and, as a routine, we prefer to allow our tests to stand at room temperature for an hour before they are put into the air oven. A large quantity of agglutinin is thus fixed before the effect of heat comes into play.

(b) Spontaneous agglutination.—When first using the hot air oven we failed to appreciate the importance of preventing evaporation from the tubes, and as a result of this some anomalous effects were observed. Cases were found where complete agglutination in coarse flocculi occurred in an irregular manner in the tubes, picking out the controls or serum containing tubes impartially. We found that this was stopped either by preventing evaporation or by using tap-water saline, which was slightly alkaline, for all purposes instead of the distilled water saline. It seems probable that the phenomenon is caused by "acid agglutination," the critical degree of acidity being produced at one stage of the evaporation.

5.—*Absorption of Agglutinin Tests.*

The agglutinin-absorbing power of a coccus was tested as follows:—

A suspension of the coccus to be tested was made up as already described to the thick standard, four times the thin standard for agglutinations.

Four samples of this suspension were then diluted with equal parts of the four monovalent sera and placed in the incubator for about one hour. They were then allowed to stand overnight at room temperature. The four tubes were then centrifuged, and the agglutinating power of each supernatant portion was compared with that of an unabsorbed sample of serum against a standard homologous coccus.

In such an experiment it is found that the Type I serum for instance has lost the whole of its agglutinating action upon the standard Type I coccus, as a result of the absorption with the unknown coccus, while the unabsorbed serum may agglutinate the standard Type I coccus to 1 in 800.

From such a result it is deduced that the unknown coccus belonged to Type I.

This method of carrying out absorption tests is simpler than some which have been recommended. It has been found to be quite satisfactory in working, and it may be doubted whether the test still requires to be performed with so much attention to detail.

Proceed as follows:—

Take 0·5 c.c. of each of the four monovalent sera diluted 1 in 25 with tap-water carbolic saline; place these quantities in small agglutination tubes, and add to each an equal quantity of the strong suspension of the coccus under examination. Put up at the same time a similar series with carbolic saline in the place of the coccus suspension.

Shake these up well. And allow both series to stand for one hour at 37° C. and then overnight at room temperature.

At the end of this time centrifuge the tubes at a fairly high speed till all the cocci have deposited, leaving a clear supernatant fluid. We now have two samples of each of the four sera

diluted 1 in 50: the first has had any agglutinins it may possess for the coccus in question absorbed from it, the second is the unabsorbed control.

From each of these eight samples measure out into eight series of four agglutination tubes the following quantities: 0·4 c.c., 0·2 c.c., 0·1 c.c. and 0·05 c.c.: making up the quantities to 0·4 c.c. with carbolic saline in the last three cases.

To each of these four dilutions now add 0·4 c.c. of the suspension of the standard coccus corresponding to the serum.

This gives dilutions of 1 in 100, 1 in 200, 1 in 400 and 1 in 800 of each of the sera, that is 16 tubes for each case and 16 tubes as a control. These are now incubated for twenty four hours at 55 C., as for agglutination tests.

The agglutinating properties of the absorbed sera are now compared with those of the unabsorbed, and any diminution in the titre is noted. The result of an agglutination and absorption test on a coccus would be recorded as in Table 22.

TABLE 22.

The Reactions of a Coccus from the Cerebro-Spinal Fluid which agglutinated with Type I and III sera (1 in 200), but was shown to belong to Type I only by absorption test.

No. 687. Source: Cerebro-Spinal Fluid	Agglutinating Sera					
	I	II	III	IV	Dextrose	Control
Agglutination by standard sera in dilution 1 in 200	—	0	+	—	—	0
Absorption with	I	II	III	IV		
	1 in 100 200 400 800	1 in 100 200 400 800	1 in 100 200 400 800	1 in 100 200 400 800		
Standard sera absorbed with coccus under examination, and tested on homologous standard coccus	0 0 0 0	— — — —	0 — — —	0 — — —		0
Standard sera unabsorbed and tested on homologous standard coccus			0 — — —	0 — — —		0

6. *The use of Monovalent or Polyvalent agglutinating Serum for diagnostic purposes.*

The use of monovalent sera for the identification of meningococci entails a considerable increase of work over what it necessary when using a polyvalent serum and the questions arise whether the advantages of the monovalent sera are important and whether the polyvalent serum is efficient.

(c) *Monovalent sera.*—Advantages.—The injection of monovalent serum it is possible to [illegible] more relevant insight into [illegible] logical problems.

For this reason alone they are essential for any worker who desires to throw light upon many of the problems connected with this disease.

The original practical advantages relating to treatment which were originally suggested do not appear to be so [illegible] important. It was, for instance, thought necessary to determine the type of an infecting [illegible] in order to select the appropriate curative serum, but it is doubtful whether this procedure has any useful value.

Disadvantages.—It is sometimes stated that a monovalent serum is more liable to fail to agglutinate certain meningococci, especially Type II meningococci, than a polyvalent serum but if the matter is tested with a certain good Type II strain there appears to be very little difference between the two types of serum.

On page 21 it is seen that seven meningococci agglutinated by Type II strains three were agglutinated with both monovalent and polyvalent sera. One gave feeble agglutination with both, while one gave slight agglutination with the monovalent serum and none with the other. Two agglutinated normally with the polyvalent serum, and of these one agglutinated slightly and the other not at all with the monovalent.

When, however, unconvalescent strains are tested it is seen that an appreciable number of strains agglutinate with Flexner's serum, but not with the monovalent sera.

In a random selection of 13,000 men there were 120 instances of this phenomenon, that is to say no less than 27 per cent. of the "positives" agglutinated with Flexner's serum and not with the type serum.

Such a large proportion necessitated the carrying out of absorption tests on a number of these strains. It was then found, as shown on p. 39, that only 16 of the 41 strains tested absorbed agglutinin for Gordon's types, and therefore only 16 could be classed as "epidemic" meningococci. If the polyvalent serum had not been used these 16 cases would have been overlooked.

For convenience we roughly calculate that half of the Flexner positive strains are "epidemic" meningococci instead of the fraction $\frac{16}{41}$, and thus $\frac{1}{2} \times 120 = 60$ of the carriers, or 15 per cent. of the carriers would have been lost without the polyvalent serum. In this respect, therefore, the use of monovalent sera alone is a considerable disadvantage for epidemiological purposes.

(*b*) *Polyvalent sera.*—*Advantages.*—The use of this serum not only does away with a number of tubes for the diagnosis of each case but also with the necessity for preparing animals of small size when a large quantity of serum is required. It is therefore very convenient for dealing with large numbers. Further, Flexner's polyvalent serum does not absolutely debar the user from the determination of Gordon's types in certain

cases because a modified form of absorption test can be carried out with it, using standard suspensions of Gordon's cocci.

The following is an example of such an absorption test :—

Experiment.—Technique as for ordinary absorption tests. Flexner's serum being diluted 1 in 25 and then mixed with an equal quantity of suspension of cocci.

	Standard Type Cocci.											
	I			II			III			IV		
Dilution of Flexner serum absorbed = 1 in 25 × ...	1 in 100	200	400	1 in 100	200	400	1 in 100	200	400	1 in 100	200	400
Flexner serum, unabsorbed ...	+	+	+	+	+	+	+	+	+	+	+	+
Flexner serum, absorbed with Type I coccus ...	0	0										+
Flexner serum, absorbed with Type II coccus ...				0	0							+
Flexner serum, absorbed with Type III coccus ...	+						0	0	0			+
Flexner serum, absorbed with Type IV coccus										0	0	0

This experiment clearly indicates that absorption with a Type I coccus removes practically all agglutinins for that type. Type II absorption is not so complete, but, nevertheless obvious. Type III is complete and also Type IV. If, therefore, the type of an unknown coccus is required to be known, it is merely necessary to mix the suspension with Flexner's serum and then test the serum absorbed and unabsorbed in three dilutions against the four standard cocci.

It is, of course assumed that the serum to be used is in all cases truly polyvalent. This point must be carefully tested with standard type suspensions before the serum is used for any purpose.

The following experiment shows the agglutinating action of three different samples of Flexner's serum :—

		Dilution of Serum.				
	Test Cocci.	100	200	1 in 400	800	1,600
Serum marked July 15th, 1916	I			+		0
	II					0
	III					0
	IV				+	0
Serum marked July 17th, 1916	I			+		
	II					
	III					
	IV			+		
Serum marked Feb. ... 10, 1917	I			+		
	II			+		
	III			+		
	IV			+	+	

It is thus seen that Flexner's serum is equally effective against all types of cocci to a high titre. The serum marked July 15th, 1915, is feebler in action, but this is no doubt accounted for by the fact that the bottle had been at room temperature in the laboratory for nearly a year at the time of the test.

Disadvantages.—The disadvantage of the polyvalent serum lies in the fact that according to our results its action is not specific. By this statement we do not necessarily mean that it has an agglutinating action in cocci which are clearly not meningococci with different cultural and biological tests, but that it includes among its "positives" a number of "meningococcus group" bacteria which cannot be classified according to the types of Gordon and therefore we are satisfied cannot be accepted as "epidemic meningococci."

As already indicated, among the 13,060 men examined 120 agglutinated with the polyvalent serum only, and about half of these were nevertheless proved by absorption tests to be "epidemic" meningococci. Consequently, about half could not be accepted as epidemic meningococci. If, therefore, we had relied on this serum alone we should have obtained 440 carriers in 13,060 instead of 380, or 3·3 per cent. instead of 2·9 per cent., and the carriers would have been isolated for an even longer time than was actually the case with monovalent sera.

The cause of this lack of specificity is clearly the excessive "group action" which is induced by the use of all types of cocci as an antigen for the immunization. This may be illustrated by alternating Flexner's serum with the four Gordon type cocci, when not only the agglutinins for the type cocci will disappear but also those for the pure "Flexner" coccus.

Experiment.—3·67 c.c. of the standard thick suspension of each of the four "type" cocci mixed together and 3 c.c. of undiluted Flexner's serum added. This makes a dilution of serum 1 in 20. The experiment is then continued as usual:

	Dilutions of Serum.			
	1 in 100	1 in 200	1 in 400	1 in 800
Type I. serum, emulsion and mixed as "Flexner" serum No. 115	—	0	—	—
Type II. serum, emulsion and mixed as "Flexner" serum No. 115	—	0	—	—
Type III. serum, emulsion and mixed as "Flexner" serum No. 115	—	0	—	—
Type IV. serum, emulsion and mixed as "Flexner" serum No. 115	—	0	—	—
Types I., II., III. and IV. mixed as "Flexner" serum No. 115 and tested on Types I., II., III. and IV.				

By Type No. I. at 1·30 [illegible] Type No. I. at 1·80 [illegible]

	Serum.			
	1 in 50	1 in 200	1 in 400	1 in 800
Flexner serum, unabsorbed, tested on Type I cocci ...				
Flexner serum, absorbed, tested on Type II cocci				
Flexner serum, unabsorbed, tested on Type III cocci				
Flexner serum, unabsorbed, tested on Type IV cocci				
Flexner serum, unabsorbed, tested on No. 113 cocci...	+	+	+	0
Flexner serum, absorbed with Types I, II, III and IV together, tested on Type I cocci			0	0
Flexner serum, absorbed with Types I, II, III and IV together, tested on Type II cocci		0	0	0
Flexner serum, absorbed with Types I, II, III and IV together, tested on Type III cocci		0	0	0
Flexner serum, absorbed with Types I, II, III and IV together, tested on Type IV cocci	0	0	0	0
Flexner serum, absorbed with Types I, II, III and IV together, tested on No. 113 cocci	0	0	0	0

Thus absorption of Flexner's serum with the type cocci not only removes practically all agglutinins for the type cocci but also for Flexner's coccus No. 113.

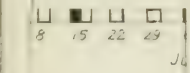
To sum up this question the "type" sera are indispensable for accurate work in connection with cerebro-spinal fever, but they will overlook a small number of carriers. Flexner's serum, on the other hand, will give rather too many carriers, and in practice it will not be practicable to show by absorption tests which of these are not "epidemic" meningococci.

It thus becomes a question whether it is better to intern too many or too few men, and this is a matter which has to be viewed from too many aspects to discuss in this place.

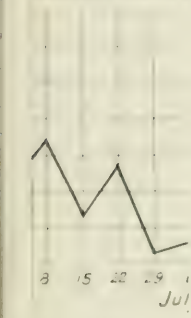
Personally we always use both Gordon's sera and Flexner's serum, but we do not intern a man on a positive result with Flexner's serum alone. When we take every aspect of this subject into consideration we prefer to run whatever trifling risk there is in allowing a "Flexner" carrier to be at large.

When, however, we are called upon to recommend a method when the work is to be carried out under unsatisfactory circumstances outside a properly equipped laboratory, we advise Flexner's serum to be used alone.

CHART 5.—POSITIVE CULTURES AT CASUALTY ROLL CO. ROYAL NAVAL HOSPITAL, PORTSMOUTH.



GOCOCCI IN NE



AL FEVER ARI
YPES II & IV.

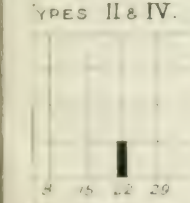


CHART Nº 4. INCIDENCE PER CENT OF N P. MENINGOCOCCI IN NEW ENTRIES, ARRANGED ACCORDING TO TYPE OF COCCUS.
BLACK - TYPES I & III. WHITE - TYPES II & IV.

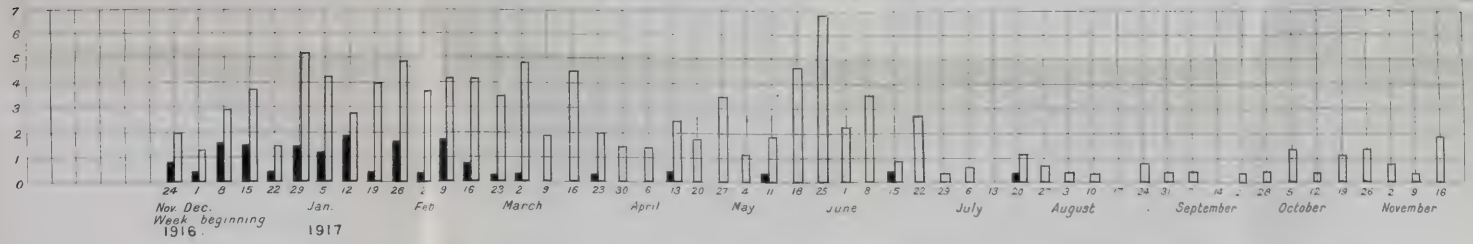


CHART Nº 3. INCIDENCE PER CENT OF N P MENINGOCOCCI IN NEW ENTRIES.

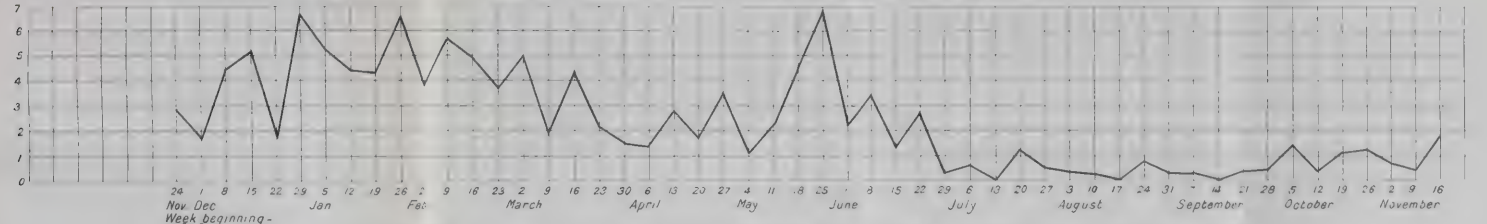


CHART Nº 2. INCIDENCE (ACTUAL) OF CASES OF CEREBRO-SPINAL FEVER ARRANGED ACCORDING TO TYPE OF COCCUS.
BLACK - TYPES I & III WHITE - TYPES II & IV.

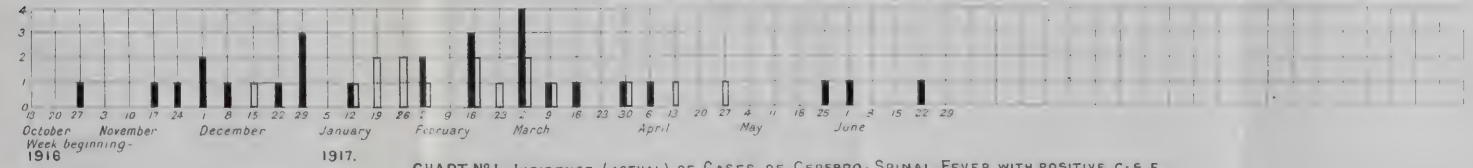


CHART Nº 1. INCIDENCE (ACTUAL) OF CASES OF CEREBRO-SPINAL FEVER WITH POSITIVE C.S.F.
(SUPERIMPOSED DOTTED CURVE IS INCIDENCE IN 1915-16.)

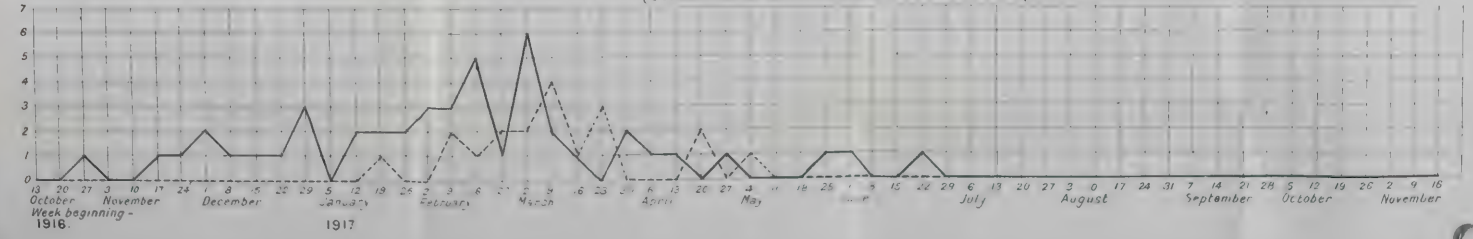


CHART 5.—POSITIVE CARRIERS AND CASES IN ROOM 60, ROYAL NAVAL HOSPITAL, PORTSMOUTH.

Key to meaning of Chart.

The fine lines indicate the total time during which various individuals were present in a room. The dotted lines link up two visits of one man, the interval being spent elsewhere.

The thick black lines ending in crosses are cases, the cross showing the date of onset.

Black dots: three throat examinations with positive result.

White dots show negative examinations.

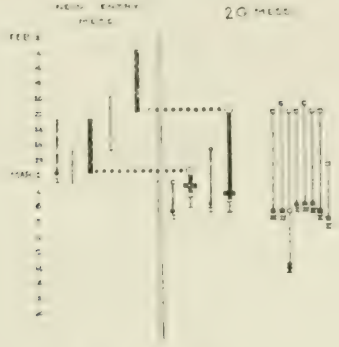
Thin white lines show time during which a man was negative.

Thin black lines show time during which a man was positive.

Thin interrupted lines show the time preceding the first positive swab during which the men were have been positive.

Roman numerals refer to the type of the cases and carriers.

CHART 6.—POSITIVE CARRIES AND CASES IN 2 O MESS, ROYAL NAVAL BARRACKS, PORTSMOUTH.



(Continued on page 20.)

As in Chart 5. Carries of 3 different types of cocci to the 2 mess are compared in a group apart. The squares have the same significance as the dots. These men all entered the mess from the receiving mess on the day of their negative test. To the left hand side of the vertical line the time spent in the mess cutter mess is shown and to the right the time in 2O mess. The new entry men in this case was not a residential mess, the men were boarded out in different parts of the barracks. Thus it does not follow that men collected at one another in the mess except accidentally outside on the mess way.

II. THE TREATMENT OF CEREBRO SPINAL MENINGITIS BY ANTI-MENINGOCOCCUS SERUM AT THE ROYAL NAVAL HOSPITAL, HASLAR, 1915–16–17.

By Staff Surgeon G. P. Adshead, M.B., Ch.B., R.N.

CONTENTS

I.—Introductory 89
1. Differential Diagnosis 90
2. Initial Symptoms 91
3. Influence of Type of Disease . . . 91
4. Serum Treatment 92
II. Observations on 1915–1916 Series . . . 92
1. Procedure on Lumbar Puncture . . 93
2. Sera Employed 93
3. Tabular Statement of Symptoms and Treatment . . 94
4. Notes on Individual Cases . . . 96
5. Temperature Charts 101
6. Conclusions Drawn 108
III. Observations on 1916–1917 Series . . . 108
1. Procedure on Lumbar Puncture . . 109
2. Sera Employed 109
3. Tabular Statement of Symptoms and Treatment . . 110
4. Notes on Individual Cases 121
5. Temperature Charts 128
6. General Conclusions 152
Appendix 154

Introduction

The clinical side of cerebro-spinal meningitis appears to interest few people of the many who are attempting to combat this disease.

The whole subject is overshadowed by the dread of harbouring carriers in our midst—consequently the major part of present literature and publications on this disease is given over to the bacteriologist and to preventive medicine.

And yet experience tends to show that it is a disease of very low infectivity.

How many cases of cerebro-spinal meningitis in its present endemic form can be definitely traced to a carrier? And again, how many known carriers have developed the disease?

In our experience no such case has occurred.

Nevertheless, although the infectivity is low, the mortality from the actual disease is high, and thus the clinical side of the cases merits greater attention and certainly provides endless interest for the clinician.

Although our results are not as successful as could be wished or hoped for in the future, we trust that the following series of cases, all personally observed and personally treated throughout, will throw some light on treatment if only by showing where errors of judgment were made.

Our cases were received into hospital from ships and naval and marine establishments belonging to the Portsmouth command. Owing to the stringent naval regulations for the isolation of suspects, many cases were sent to hospital for "observation" cerebro-spinal meningitis, and a useful purpose may be served by mentioning a few of the types of cases so received but proved to be innocent.

1. *Differential Diagnosis.*

Headache is so initial symptom of many diseases, and severe headache, especially in occipital cases, so frequently causes the patient to assume the posture of slight retraction that this symptom was a frequent cause of wrong diagnosis.

Tonsilitis with enlargement of cervical glands producing some stiffness of the neck, came second.

This error was perhaps caused by a wrong assumption by the casual observer that a disease which has its primary origin in throat infection must of necessity show throat inflammation.

The exact reverse is our experience. Cases of cerebro-spinal meningitis seldom show throat symptoms or signs other than those common to all pyrexial diseases.

Rashes.—Amongst diseases accompanied by a rash the following were wrongly suspected of being cerebro-spinal meningitis:—

(1) Rubella, on account of its initial symptom of pain in the region of the neck caused by glandular enlargement;

(2) Measles, again on account of glandular enlargement and stiffness of the neck, accompanied by headache and the characteristic prodromal rash.

Flea bites and *bug bites* were the cause of error in a few cases, perhaps on account of the purpuric characteristics of the skin-puncturing resulting from such bites, and which, if profuse, may

cause constitutional disturbance in one not used to such attacks, or the constitutional symptoms were due to some other recognised disease.

Cases of cerebral apoplexy, delirium tremens and even *acute alcoholism* have been received. In fact our observation cabins have been the clearing house of many panic diagnoses which, however, presented little difficulty in the absence of the cardinal symptoms of cerebro-spinal meningitis.

Meningites. A certain number of cases of meningitis due to organisms other than the meningococcus came under observation. Since these presented definite signs and symptoms, they had anti-meningococcic serum injected at primary lumbar puncture, it being our custom to give serum when symptoms of meningitis were present before confirmation or negation by the laboratory, but since these cases on "negative" laboratory report passed out of our hands, no further reference is made to them.

Seventy one cases are discussed in this article, and to our knowledge failure to diagnose has not occurred. Even in the most fulminating cases confirmation of clinical diagnosis was always obtained from the laboratory prior to death. Absolute failure to find the meningococcus only occurred in four cases, viz., W. 18, 37, 43, but the presence of pus in the cerebro-spinal fluid, combined with the positive clinical signs, warrants their inclusion as definite cases of the disease.

2 *Initial Symptoms*

Among the initial symptoms on which the primary diagnosis was made, the undermentioned were the most prevalent and constant:

Headache of varying degree was present in all cases who could describe their symptoms.

Neck Symptoms. Twenty nine had retraction; thirty eight complained of and exhibited stiffness only and four had no definite alteration from the normal.

Mental Symptoms. Eleven cases were comatose; thirty nine cases were semi-conscious, drowsy or irritable; one case was hilarious; twenty cases were perfectly rational.

Kernig's sign was definite in sixty six cases.

Rashes of various intensity and distribution were present in forty two cases.

3 *Influence of "Type" of Infection.*

In the 1916-1917 series, when the advances in bacteriology allowed one to know what types (Gordon) of meningococci were infecting the patient, an attempt was made to discover if there was any connexity between type and incidence, clinical symptoms and mortality.

The figures are given for they appear to be without significance from a clinical point of view. Too few cases were treated for there to be any certainty as to the clinical severity of any particular type.

Months	Total	Type					Deaths	Type of fatal cases				
		1	2	3	4	5		1	2	3	4	5
October	1				1							
November	2	2										
December	6	1	1	1					1			
January	8	2	2	1	3			1	1		1	
February	13	1	3		3	1	3	2	1			
March	10	5	3			2	3	2	1			1
April	5	2	2			1						
May	2	1			1							
June	2	1		1								
Totals	49	24	11	3	8	4	15	7	5		2	1

* The figures refer to cases in which [illegible] the meningococcus and have nothing to do with type.

4. Serum Treatment

Serum treatment by injection into the thecal cavity, after removal of cerebro-spinal fluid, was first carried out as a routine procedure in the Royal Naval Hospital, Haslar, in October, 1915.

Previously this method of treatment had been employed but no apparent trust was placed in it or in the sera, and other forms of treatment were also used.

Since October, 1915, all cases have been treated with serum without other treatment.

In 1915-1916 various sera were used, but since the introduction of Flexner's sera 1915-1916-1917, these have entirely superseded the others, except on two occasions when the serum made by the Mulford Institute was tried hoping that it might contain the necessary immunising body.

II. Considerations of 1915-1916 Series.

From October, 1915, to September, 1916, twenty-two cases were treated, all except one proved by finding the meningococcus in the cerebro-spinal fluid. Of these twenty-two cases, eighteen recovered, and of these sixteen returned to duty and two were

invalided out of H.M. Navy—one on account of age and one for slow cerebration, which might have been present before.

This gives a mortality of 18·22 per cent., which was gratifying and gave one a sense of security in the methods employed.

1. *Procedure of Lumbar Puncture.*

In all cases except those in which coma was present, on completion of systematic examination, lumbar puncture was performed under scopolomorphine.

A hypodermic injection of the following was given :

R. Scopolamine	...	grs. 1/100.
Morphine Sulp.	...	grs. 1/6.
Atropine Sulp.	...	grs. 1/100.

An interval of thirty minutes was allowed to elapse, when local preparation of the skin with acetone and Tinct. iodine was carried out with as little disturbance to the patient as possible.

Lumbar puncture was then performed with the patient lying on the side—knees well drawn up and the buttocks well over the edge of the bed.

The instruments used were Barker's needles and a 20 c.c. "Record" syringe, fitted with an adapter.

The serum was raised to a temperature of 100° F. by standing the phial in hot water.

The quantity of cerebro-spinal fluid withdrawn varied according to the pressure, but seldom was more than 30 c.c. withdrawn. In conscious cases the indication for cessation was taken from the patient complaining of increased headache.

Serum was then injected slowly by the syringe.

The use of scopolomorphine injection was found to obviate all objection of the patient to lumbar puncture, while the quiet sleep promoted by the drugs, for a long period following operation, appears to have been beneficial.

A smart purge, viz., calomel, grs. iv, followed by Epsom salts in eight hours, was always administered if the patient was not unconscious. Even in the unconscious patients it was usually found that reflexes allowed of the administration of liquid purges such as castor oil.

The foot of the bed was raised on blocks about 8 to 10 inches.

2. *Sera Employed.*

1. Polyvalent. Mulford Institute.
2. Polyvalent. Pasteur Institute. P.I. 3619.
3. Gordon, No. 1. Pasteur Institute. P.I. 3636.
4. Gordon, Nos. 2 and 3. Pasteur Institute. P.I. 3639.
5. Flexner, 1915. Rockefeller Institute.
6. Flexner, 1916. Rockefeller Institute.

(B 2)

3. *Tabular Statement of Symptoms*

Case and Age	Date of Onset	Date of Admission	General Condition	Nerve Muscular System: Knee Jerk	Nerve Muscular System: Nerves	Incont.	Dates of Lumbar Punctures
A. 19 years	Oct. 1	Oct. 4	Drowsy, Headache	+	Retraction	—	Oct. 4
B. 14 years	Oct. 7	Oct. 11	Restless, Fright ened	+	Retraction	—	Oct. 11
C. 18 years	Jan. 21	Jan. 21	Comatose	0	Stiff	+	Jan. 21
D. 19 years	Feb. 11	Feb. 12	Comatose	+	Much Re traction	—	Feb. 12 Feb. 15
E. 15 years	Feb. 14	Feb. 14	Hilarious	—	No	—	Mar. 2 Mar. 5
F. 16 years	Feb. 16	Feb. 17	Restless Uncon scious	+	Retraction	—	Feb. 17
G. 17 years	Feb. 24	Feb. 25	Conscious Semi-conscious	—	Stiff	—	Feb. 25 Feb. 29 Mar. 5 Mar. 6 Mar. 12
H. 19 years	Mar. 4	Mar. 5	Comatose	+	Retraction	+	Mar. 5 Mar. 6
J. 26 years	Mar. 6	Mar. 7	Conscious, Irri table	+	Retraction	—	Mar. 7
K. 19 years	Feb. 16	Mar. 7	Lethargic	0	Retraction	—	Mar. 7 Mar. 8
L. 20 years	Mar. 8	Mar. 9	Irritable	+	Stiff	—	Mar. 9
M. 12 years	Mar. 10	Mar. 11	Semi-conscious, Resistant	0	Retraction	+	Mar. 11 Mar. 16
N. 9 years	Mar. 13	Mar. 13	Semi-conscious, Resistant	+	Stiff	+	Mar. 13 Mar. 31
O. 18 years	Mar. 14	Mar. 14	Semi-conscious	+	Retraction	+	Mar. 14 Mar. 16
P. 13 years	Mar. 22	Mar. 29	Violent Headache	+	No	—	Mar. 22
Q. 10 years	Mar. 29	Mar. 29	Headache	+	Retraction	+	Mar. 29 Mar. 30

and Treatment. 1915-1916 *Series.*

Cerebro-Spinal Fluid Condition and Depletion	Serum and Dose	Remarks on Progress.	Complications.	Result.
Turbid — 20 c.c.	Mulford + 20 c.c.	Slow recovery ..	Slow cerebration.	Invalided.
Clear — 15 c.c.	Mulford + 15 c.c.	Rapid recovery .	None ...	Invalided.
Turbid — 20 c.c.	Mulford + 10 c.c.	Rapid recovery .	None ...	Duty.
Very Turbid — 40 c.c.	Mulford + 30 c.c.	Became rational .		
Less Turbid — 30 c.c.	P. I. 3619 + 6 c.c. Gordon 1 + 10 c.c.	Developed Pneumonia, but quite rational.	Broncho-pneumonia.	Dead, 4 days.
Clear — 10 c.c.	No serum	Slow recovery	None ..	Duty.
Turbid — 15 c.c.	P. I. 3619 + 20 c.c.			
Turbid — 25 c.c.	P.I. 3619 + 10 c.c. Gordon 1 + 10 c.c.	Rapid recovery ...	None ..	Duty.
Turbid — 20 c.c.	Gordon 1-23 + 20 c.c.	No improvement .		
— 25 c.c.	Gordon 1-23 + 20 c.c.	Little improvement.		
Clearer — 40 c.c.	P.I. 3619 + 20 c.c.	Improvement, but relapse.		
Turbid — 30 c.c.	P.I. 3619 + 20 c.c.	Rapid recovery.		
Pus — 40 c.c.	Flexner 1915 + 20 c.c.		None ...	Duty.
Turbid — 30 c.c.	P.I. 3619 + 20 c.c.	Improvement	Broncho-pneumonia.	Dead, 4 days.
— 20 c.c.	P.I. 3619 + 20 c.c.			
Turbid — 35 c.c.	P.I. 3619 + 20 c.c.	Rapid recovery	None .	Duty.
Clear — 20 c.c.	No serum	Was very wasted on admission. Rapid convalescence.	None	Duty
Clear — 20 c.c.	P.I. 3619 + 20 c.c.			
Clear — 40 c.c.	P.I. 3619 + 30 c.c.		Heart failure	Dead, 9½ hours.
Turbid — 30 c.c.	Flexner 1915 + 20 c.c.	General improvement		
Clear — 30 c.c.	Flexner 1915 + 20 c.c.	Recovery, but slow	None ...	Duty.
Very Turbid — 30 c.c.	Flexner 1915 + 20 c.c.	Good improvement, but relapse.	Serum Joints; Otitis Media (chronic), Bronchitis.	Duty.
Turbid — 30 c.c.	Flexner 1915 + 20 c.c.	Immediate recovery		
Turbid — 30 c.c.	Flexner 1915 + 20 c.c.	Became conscious		
Turbid — 25 c.c.	Flexner 1915 + 20 c.c.	Rapid convalescence	None	Duty.
Turbid — 30 c.c.	Flexner 1915 + 20 c.c.	Immediate recovery	None	Duty.
Opalescent — 30 c.c.	Flexner 1915 + 20 c.c.	Improvement		
Turbid — 20 c.c.	Flexner 1916 + 15 c.c.	Rapid recovery	None	Duty.

3. *Tabular Statement of Symptoms*

Case and Age	Date of Onset	Date of Admission	General Condition	Neuro-Muscular System: Kernig	Neuro-Muscular System: Neck	Rash	Date of Lumbar Puncture
R. 21 years.	Mar. 27	Mar. 28	Unconscious, very Violent	+	Retraction	+	Mar. 28
S. 17 years.	Mar. 27	Mar. 28	Headache		Retraction	+	Mar. 28
T. 30 years.	Apl. 24	Apl. 24	Frightened	+	Nil	+	Apl. 24
							Apl. 28
							May 20
U. 19 years.	Apl. 23	Apl. 24	Rational ...		Retraction		Apl. 24
							Apl. 26
V. 17 years.	May 6	May 6	Rational ...		Rigid		May 6
							May 7
W. 28 years.	June 4	June 5	Rational		Stiff	+	June 5

4. *Notes on Individual Cases.*

Brief comments on the Tabular Statement and Temperature Charts.

Case A.—No chart is available for this man.

He ran a very chronic course with persistent headache and kernig's sign, but his symptoms were never severe enough to suggest further intervention. After being ill for thirty days he suddenly developed rapid convalescence, but slow cerebration remained.

Case B.—This man was under observation for measles for five days previous to coming under our observation.

He made a rapid recovery after one injection of Mulford serum, but was invalided on account of age, returning to his former employment as an ordinary labourer.

Case C.—This man was on his eleventh day of measles when he developed cerebro-spinal meningitis. Consciousness returned and symptoms disappeared within twelve hours of injection of 10 c.c. of Mulford serum.

Case D.—This case was a very severe one from the onset, but showed some improvement and he was conscious after the first lumbar puncture and administration of 80 c.c. Mulford serum. However he relapsed on the third day. On the second lumbar puncture Mulford serum being not available, a polyvalent serum of [illegible] was used. After the second injection of 80 c.c. he was conscious and rational, and the temperature became normal immediately.

He developed measles on admission and died on the fifth day.

Case E.—This case was not a very severe one, as can be seen by the temperature chart. He was thought to be suffering from enteric fever on admission. He presented the meningeal symptoms, and was given 80 c.c. [illegible] Mulford.

nd Treatment. 1915-1916 *Series*—continued.

Cerebro-Spinal Fluid. Condition and Depletion.	Serum and Dose.	Remarks on Progress.	Complications.	Result.
Turbid — 30 c.c.	Flexner 1916 + 20 c.c.	-	Heart Failure	Dead. 8 hours.
Turbid — 25 c.c.	Flexner 1916 + 20 c.c.	Rapid recovery ...	None ...	Duty.
Turbid — 30 c.c.	Flexner 1916 + 20 c.c.	Rapid recovery ...	Pericarditis; Delirium Tremens.	Duty
Turbid — 22 c.c.	Flexner 1916 + 20 c.c.	Developed Pericarditis.		
Opalescent — 30 c.c.	Flexner 1916 + 20 c.c.	Rapid convalescence.		
Yellow Pus — 5 c.c.	Flexner 1916 + 20 c.c.	Improvement	None ...	Duty.
Turbid — 30 c.c.	Flexner 1916 + 20 c.c.	Cessation of symptoms.		
Clear — 10 c.c.	No serum	Rapid convalescence ...	None ...	Duty.
Clear — 20 c.c.	Flexner 1916 + 20 c.c.			
Turbid — 25 c.c.	Flexner 1916 + 20 c.c.	Rapid convalescence ...	None ...	Duty.

He used to laugh without reason, and was always quietly singing through the nursery rhymes or whistling Gilbert and Sullivan opera, and when corrected pleaded ignorance of what he was doing.

He was not lumbar punctured until his eighteenth day under observation, all other diseases having by this time been ruled out.

Lumbar puncture alone had no effect on his mental condition, and, as difficulty was experienced in finding the meningococcus in his cerebro-spinal fluid, the laboratory report was delayed until the twenty-first day, when the result being a positive he was lumbar punctured again and 20 c.c. of P.I. 3619 given.

His condition immediately improved and he only had three further rises of temperature, which were always heralded by the singing and whistling previously mentioned.

Five days after serum he became rapidly convalescent.

Case I.—Made good progress on first injection of P.I. 3619 and P.I. 3646 pooled. A similar dose was given intramuscularly on the third day.

Case G.—This case, in which P.I. 3619, 3646 and 3639 were given initiatively on four successive lumbar punctures, showed little improvement and was tending to become chronic when, on the seventeenth day, 20 c.c. of Flexner 1915 serum were given.

His symptoms rapidly disappeared and convalescence was established.

Case H.—This case was of a tuberculous type, showing some mental improvement on treatment, but died from pneumonia on the fourth day.

He received on both lumbar punctures one P.I. 3619 and 6 mils. also given intravenously.

Case I.—A severe case with very turbid fluid under pressure, who made a dramatic recovery with one injection of P.I. 3619.

Case K.—This case had been under treatment outside for fourteen days before coming under our observation.

His condition on re-entry was one of marked lethargy, great wasting, and incontinence of fæces and urine.

The first lumbar puncture was for diagnosis, but he received his injection of P.I. 3619 within twenty hours.

His immediate improvement and rapid convalescence were particularly dramatic, for so ill a man and wasted a case.

Case L.—A fulminating case who died in nine and a half hours, allowing for little clinical observation other than that which is tabulated.

Case M.—This case was a severe one, but showed marked improvement on first injection of serum. He relapsed on the sixth day, when a second injection was given. From this time he made good progress with negative symptoms, and his chart, while demonstrating the periodicity of chronicity, is no criterion of his general condition which never caused anxiety.

Case N.—This case was one which, having shown good improvement on first treatment, was complicated by acute multiple synovitis of a rheumatic type, thought to be due to serum.

He also had chronic otitis media which again became acute, and he developed bronchitis on the eighth day.

As, however, his mental condition was satisfactory, it was not until the disappearance of complications—which would have accounted for his temperature—that a second injection of serum was given.

The dramatic result of this second injection points to the fact that he would have benefited by earlier second treatment.

Case O.—Showed marked improvement after first injection, but relapsed to unconsciousness on the third day, demanding a second injection. The result of this is clearly demonstrated on the chart.

Case P.—An interesting case with a history of having been admitted into hospital at Alexandria on January 14th, 1916, with cerebro-spinal meningitis, where he was treated by lumbar puncture also.

He was admitted into this hospital on March 21st after being convalescent since February 1st, but on account of not having had routine throat examination he was placed in our cerebro-spinal meningitis section. Within twenty-four hours of admission he presented signs of acute cerebro-spinal meningitis, and was treated by lumbar puncture and injection of Flexner serum.

The result was very dramatic, and his convalescence was rapid.

He is considered to be a case of relapse due to change of climate, and not a fresh infection. This raises the question of how long the cerebro-spinal fluid may remain infected with production of no symptoms.

Case Q.—The case requires little comment. Second treatment was performed on account of returning cerebral symptoms and secondary rise of temperature. The result is clearly demonstrated by his chart.

Case R.—A fulminating case, very virulent and running, who died in eight hours, apparently from heart failure.

This was the 5th instance of using Flexner 1916 serum.

Case S.—The second case in which Flexner 1916 serum was used.

Case T.—This case requires explanation, more than all the others, and demonstrates the difficulty in judging when to continue serum treatment and when to withhold it.

On admission the case was not severe mentally or otherwise—such symptoms which are tabulated were mild, and disappeared on first injection. On the second day he developed symptoms of delirium tremens.

On the third day he had marked rheumatic symptoms of the larger joints, now known to be meningococcal.

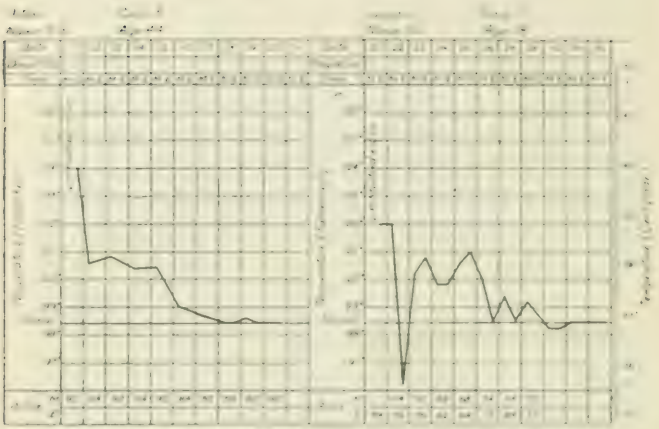
On the fifth day, the temperature having steadily risen, in the light of previous experience he was given his second injection, with apparently good result except that his rheumatism increased and he developed on the sixth day a very severe pericarditis. This was thought to account for his continued symptoms. The treatment of this pericarditis now became of the first importance in the absence of symptoms of cerebro-spinal meningitis. Signs of the presence of fluid in the pericardial sac were absent throughout, so one was denied the chance of investigating the organism causing the lesion. This latter complication had quite disappeared by the twenty-third day, when, further investigation having failed to find reason for the continuation and alteration in type of his pyrexia, lumbar puncture was performed and a third injection of serum given. There was immediate disappearance of clinical signs, and a rapid convalescence was established.

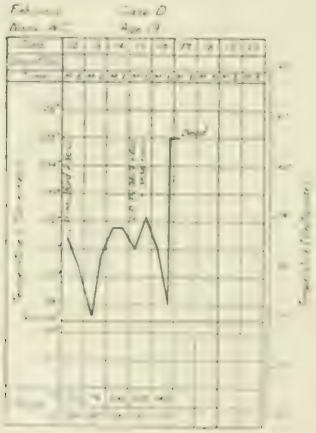
Case IV.—Another case demonstrating the necessity of second injection on account of further rise of temperature and persistence of symptoms, all of which were relieved by the treatment.

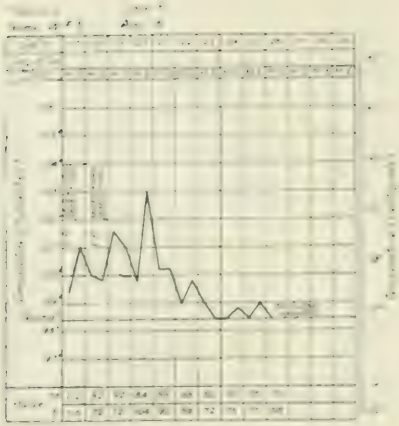
Case V.—This case was lumbar punctured on admission for diagnosis, but no serum was given as his cerebro-spinal fluid was clear and not under pressure. No improvement was noted on lumbar puncture alone, but rapid disappearance of symptoms followed second lumbar puncture and injection of serum.

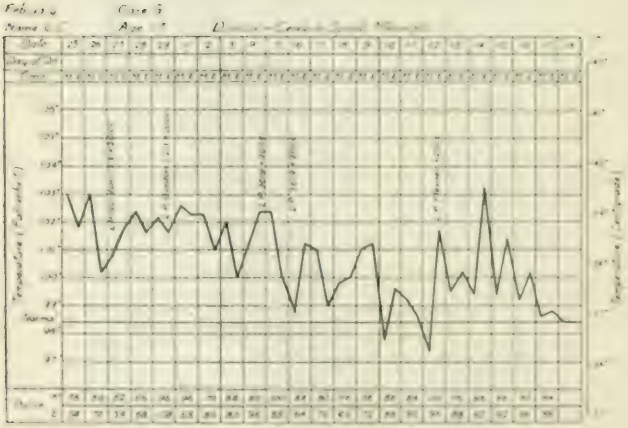
Case VI.—This last case is the only one quoted in which meningococci were not found in the cerebro-spinal fluid. He was clinically a case of cerebro-spinal fever, and his symptoms disappeared after one injection of serum.

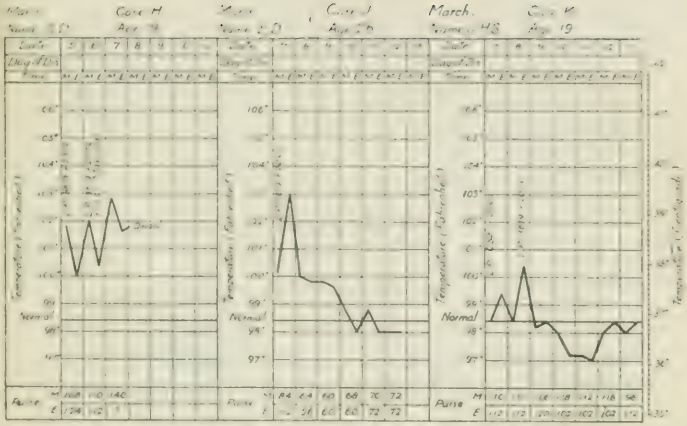
5. *Temperature Charts* 1915-1916 *Series.*

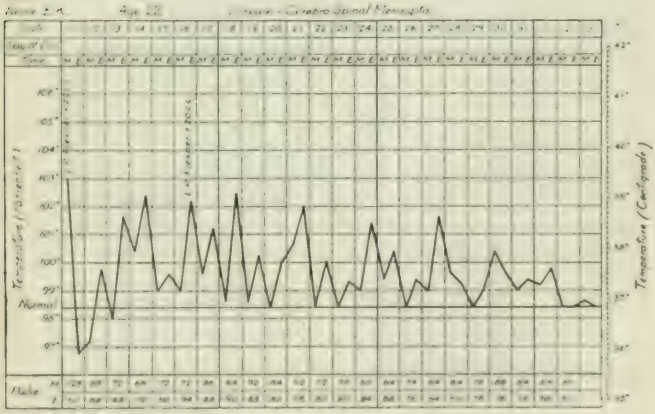


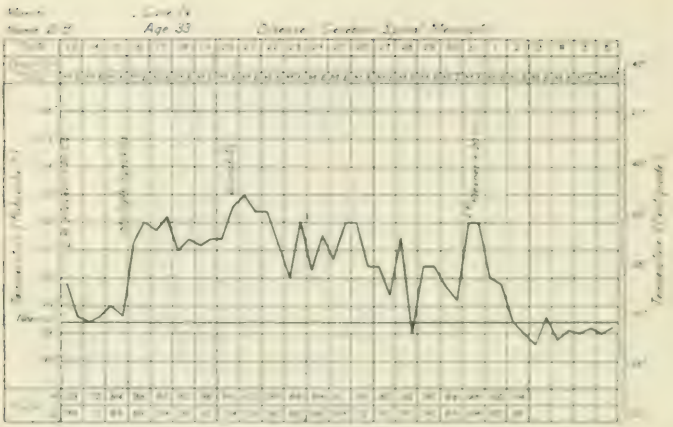


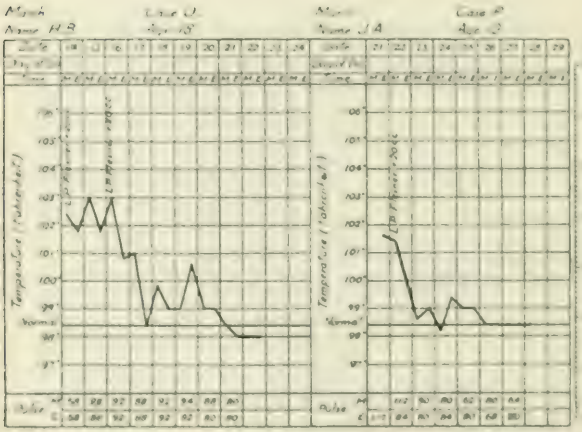


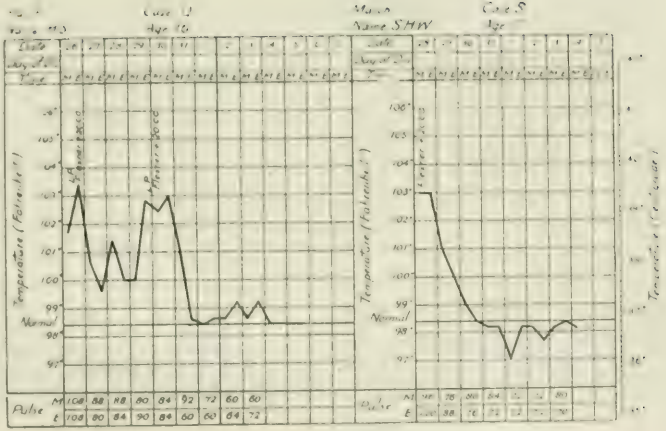


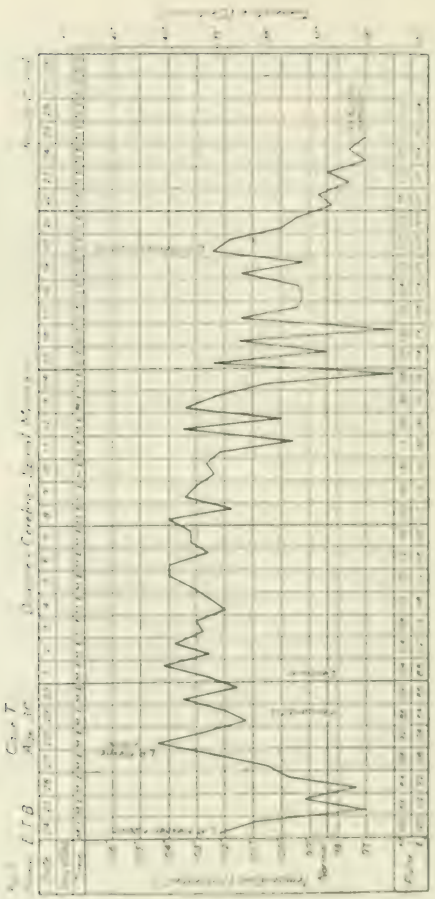

Temperature (Fahrenheit)
Temperature (Centigrade)
Normal
Pulse

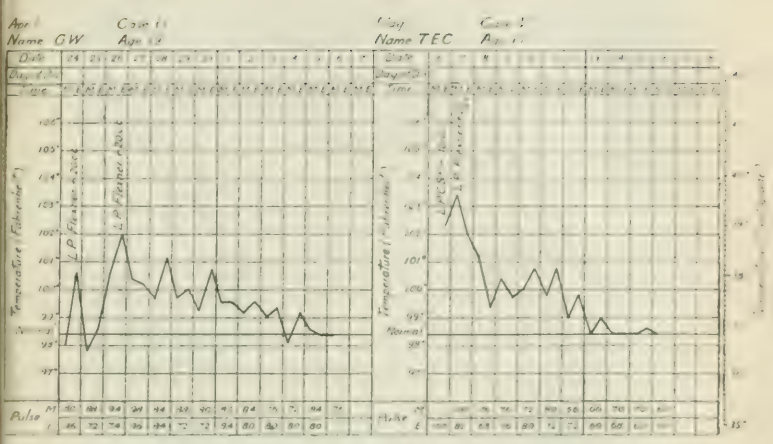

Temperature (Fahrenheit)
Temperature (Centigrade)
Normal
Pulse

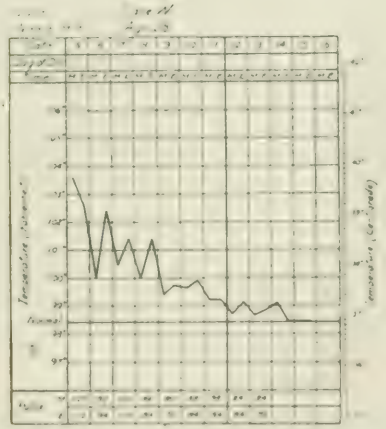

Age 33
Temperature (Fahrenheit)
Temperature (Centigrade)


Name H B
Age 18
Name J A
Age 3
Temperature (Fahrenheit)
Temperature (Centigrade)


Case II
Age 16
Name SHW
Case S
Age
Temperature (Fahrenheit)
Temperature (Centigrade)
Normal
Pulse
M
E




Name GW
Name TEC
Date
Day of Disease
Time
Temperature (Fahrenheit)
Pulse
Normal


Temperature (Fahrenheit)
Normal

c. *Conclusions Drawn.*

In view of the resulting mortality, 18·22 per cent., and the sense of security which serum treatment had given, some criticism of the sera employed may be permitted. It is, however, impossible to dogmatise over so small a series of cases, especially since some clinicians are of opinion that the symptoms of this disease can be alleviated and even cured by lumbar puncture alone. Some of our cases gave such dramatic results that it may be claimed that they do not demonstrate the efficacy of sera more than the value of lumbar puncture.

Except in one fulminating case (R) in which Flexner 1916 serum was given, the deaths occurred in cases in which French manufactured sera were employed, and these fatal cases were in no way more severe in type than those in which American sera were used. Against this however, some of the most dramatic cures were accomplished by the French serum, P.I. 3619 (Cases F, J and K). From the results we came to the conclusion—

(1) That the serum prepared by the Mulford Institute was very satisfactory until deterioration prevented its use.

(2) That Pasteur Institute serum, made from type cultures supplied by Lieut.-Colonel Gordon, was of little or no value in the type of cerebro-spinal meningitis dealt with.

(3) That the Polyvalent serum of the Pasteur Institute, **P.I. 3619, in certain cases was most satisfactory.**

(4) That Flexner serum gave excellent results in all cases except one, and was the means of establishing cure in cases which previously had refused to react to other sera.

The following deductions were also drawn—

(*a*) That, provided the serum is efficacious, frequent lumbar puncture is unnecessary.

(*b*) That there is no evidence that intramuscular injection of serum is beneficial.

(*c*) That a general anæsthetic for lumbar puncture, as recommended by some clinicians, is unnecessary if scopolomorphine is used, and there is no evidence that harm resulted from the employment of this drug.

(*d*) That aspirin appears to relieve all minor symptoms of headache and sleeplessness.

III. Consideration of 1916-1917 Series.

With these hastily formed ideas of the best method of treatment, and with an unlimited supply of Flexner serum, the autumn, the beginning of the cerebro-spinal meningitis season, was looked forward to with confidence. The first case since June was admitted on October 28th.

1. *Procedure of Lumbar Puncture.*

The same method of lumbar puncture and injection of serum was employed, but a slight change in routine was made.

It was found to be unnecessary to use scopolomorphine in all cases. In those cases which were rational on admission or became so after primary treatment it was found that the operation could be performed without any narcotic if the patient was prepared by explanation for the sensations he must expect.

No local anæsthetic even was employed, and we have never found any objection or resistance on the part of the patient which interfered with the operation.

A point noted amongst these rational and non-narcotised patients was that while depletion of cerebro-spinal fluid was in progress headache increased in violence, and that the injection of serum immediately relieved this symptom and in many cases caused its disappearance. Quiet, restful sleep following injection of serum was very common. Cramps in the legs during injection were severe in only a few cases, and were totally absent in many. We are of opinion that this symptom can be obviated by having the serum as nearly as possible at the body temperature.

A general anæsthetic had to be given in five cases, viz., 4, 5, 6, 12 and 36, on account of the violence and resistance of these men when interfered with. The anæsthetic used was ether, by the open method. Cases 4, 6 and 12 died, the mode of their deaths being stated and discussed individually later.

2. *Sera Employed.*

The serum used during this period, except on two occasions, was Flexner 1916 and 1917, prepared by the Rockefeller Institute.

The new Mulford serum was employed twice, once in Case 2 and once in Case 31, but did not appear to have any beneficial action.

3. *Tabular Statement of Symptoms*

Case and Age	Date of Onset	Date of Admission	General Condition	Neuro-Muscular System: Knee Jerk	Neuro-Muscular System: Neck	Reels	Dates of Lumbar Puncture	Cerebro-Spinal Fluid: Character and Deposit
1. 18 years	Oct. 28	Oct. 28	Semi-conscious. Resistive		Retraction		Oct. 28	Turbid — 30 c.c.
							Oct. 29	Opalescent — 40 c.c.
2. 16 years	Nov. 13	Nov. 22	Rational		Stiff	—	Nov. 26	Clear — 5 c.c.
							Nov. 26	Opalescent — 40 c.c.
							Nov. 27	Opalescent — 40 c.c.
							Nov. 29	— 25 c.c.
							Dec. 3	— 55 c.c.
3. 18 years.	Nov. 28	Nov. 29	Semi-conscious. Resistive. Terrified		Rigid		Nov. 29	Turbid — 35 c.c.
							Nov. 30	Turbid — 30 c.c.
4. 19 years.	Dec. 1	Dec. 1	Comatose		Retraction	—	Dec. 1	Turbid — 15 c.c.
							Dec. 2	Dec. — 5 c.c.
5. 22 years	Dec. 6	Dec. 6	Conscious. Resistent.		Retraction	—	Dec. 6	Turbid — 30 c.c.
							Dec. 7	Turbid — 25 c.c.
							Dec. 7	Turbid — 25 c.c.
							Dec. 10	Blood-stained — 30 c.c.
6. 18 years	Dec. 12	Dec. 13	Semi-conscious		Stiff		Dec. 13	Turbid — 10 c.c.
							Dec. 14	Very Turbid — 30 c.c.
							Dec. 15	Turbid — 45 c.c.
7. 18 years	Dec. 18	Dec. 18	Comatose		Stiff	—	Dec. 18	Opalescent — 30 c.c.
							Dec. 19	Turbid — 35 c.c.
8. 45 years.	Dec. 28	Dec. 28	Rational		Stiff		Dec. 28	Turbid — 30 c.c.
							Dec. 30	Turbid — 20 c.c.
							Jan. 2	Clearer — 10 c.c.
							Jan. 4	Clear — 20 c.c.
							Jan. 7	Clear — 12 c.c.
9. 18 years.	Dec. 31	Dec. 31	Irritable, but rational	+	Stiff	—	Dec. 31	Opalescent — 30 c.c.
10. 18 years.	Jan. 3	Jan. 3	Rational	+	Stiff	+	Jan. 3	Opalescent — 25 c.c.

and Treatment. 1916-1917 *Series.*

Serum and Dose.	Type (Gordon).	Remarks on Progress.	Complications.	Result.
Flexner 1916 — 20 c.c.	II	Became sensible . . Head still retracted.	None . .	Duty.
Flexner 1916 — 20 c.c.		Symptoms disappeared.		
	I		None . .	Duty.
Flexner 1916 — 20 c.c.		Improvement.		
Mulford — 30 c.c.		Improvement, but relapse.		
Flexner 1916 — 20 c.c.		Improvement, but relapse.		
Flexner 1916 — 25 c.c.		Symptoms disappeared.		
Flexner 1916 — 20 c.c.	I	Became rational	None . . .	Duty.
Flexner 1916 — 40 c.c.		Immediate improvement.		
Flexner 1916 — 20 c.c.	I	Restless, but coherent . .	Respiratory failure	Dead, 28 hrs.
Flexner 1916 — 40 c.c.		Stopped breathing, but restored.		
Flexner 1916 — 20 c.c.	I	Improvement	Rubella, 16th day	Duty.
Flexner 1916 — 15 c.c.		More rational.		
Flexner 1916 — 20 c.c.		Acetone smell to breath.		
Flexner 1916 — 20 c.c.		Sensible.		
Flexner 1916 — 20 c.c.	I	Developed strabismus . .	Heart failure	Dead, 58 hrs.
Flexner 1916 — 30 c.c.		Increased symptoms, but rational.		
Flexner 1916 — 20 c.c.		Heart Failure in 2½ hours.		
Flexner 1916 — 40 c.c.	II	No change		Dead, 23 hrs.
Flexner 1916 — 20 c.c.		Cerebral irritation.		
Flexner 1916 — 20 c.c.	...	Mental improvement . .	Delirium tremens	Invalided for age.
Flexner 1916 — 15 c.c.		General improvement . .		
Flexner 1916 — 10 c.c.		Delirium tremens . .		
Flexner 1916 — 12 c.c.		Improvement. Delirium tremens marked.		
No serum given		Very ill and with delirium. Made good convalescence.		
Flexner 1916 — 20 c.c.	I	Intermittent improvement . .	None	Duty.
Flexner 1916 — 15 c.c.		Temperature dropped . .	None	Duty.

3 *Tubercular Statement of Symptoms*

Case No. Age	Date of Operation	Date of Admission	General Condition	Nervous System: Reflexes	Nervous System: Sensorium	Rash	Date of Examination of Urine	Character of Urine Deposit
11. 14 years.	Jan. 4	Jan. 4	Rational		Stupid		Jan. 4	Clear — 25 c.c.
							Jan. 6	Turbid — 30 c.c.
12. 38 years.	Jan. 12	Jan. 13	Unconscious. Violent.			+	Jan. 13	Turbid Yellow — 60 c.c.
							Jan. 14	Very Turbid — 45 c.c.
							Jan. 16	Yellow — 8 c.c.
13. 18 years.	Jan. 13	Jan. 13	Unconscious. Violent.	+	Stupid	—	Jan. 13	Turbid — 35 c.c.
							Jan. 14	Turbid — 35 c.c.
							Jan. 15	Turbid — 10 c.c.
14. 18 years.	Jan. 20	Jan. 20	Frightened		Stupid		Jan. 20	Turbid — 40 c.c.
							Jan. 21	Turbid — 20 c.c.
							Jan. 22	Yellow — 18 c.c.
15. 27 years.	Jan. 20	Jan. 22	Rational	+	Stupid		Jan. 22	Turbid — 40 c.c.
							Jan. 23	Turbid — 25 c.c.
							Jan. 25	Fibrin Clots — 7 c.c.
					Stupid		Feb. 3	Clear — 25 c.c.
							Feb. 25	Turbid — 27 c.c.
			Unconscious	+	Retraction		Feb. 26	Very Turbid — 40 c.c.
16. 18 years.	Jan. 31	Jan. 31	Drowsy; Irritable.	+	Stupid		Jan. 31	Turbid — 30 c.c.
							Feb. 3	Less Turbid — 35 c.c.
17. 32 years.	Jan. 31	Jan. 31	Semi-conscious	+	Stupid		Jan. 31	Turbid — 30 c.c.
18. 31 years.	Feb. 1	Feb. 3	Rational		Rigid		Feb. 3	Opalescent — 27
19. 19 years.	Feb. 3	Feb. 4	Semi-conscious. Restless.		Retracted		Feb. 4	Opalescent — 12 c.c.
							Feb. 6	Turbid — 35 c.c.
							Feb. 8	Clear — 30 c.c.
							Feb. 14	Yellow — 27 c.c.
							Feb. 16	Clear — 17 c.c.
							Feb. 19	Opalescent — 25 c.c.
							Feb. 20	Clear — 25 c.c.

and Treatment. 1916-1917 *Series*—continued.

Serum and Dose.	Type (Gordon).	Remarks on Progress.	Complications	Result
Flexner 1916 - 18 c.c.	III	Temperature dropped relief.	Jan. 7 Left Irido Cyclitis.	Invalided.
Flexner 1916 - 20 c.c.		Disappearance of Cerebro-Spinal symptoms.	Acute Synovitis.	
		Jan. 19. Flexner 1916 - 20 c.c. muscular	Eye enucleated.	
Flexner 1916 - 30 c.c.	IV	Slight mental improvement		Dead, 87 hrs.
Flexner 1916 - 25 c.c.		More rational		
Flexner 1916 - 20 c.c.		Bronchitis.		
Flexner 1916 - 20 c.c.	I	Increase of symptoms		Dead, 67 hrs.
Flexner 1916 - 20 c.c.		Bronchial moisture		
Flexner 1916 - 30 c.c.		No change		
Flexner 1916 - 20 c.c.	II	Good improvement	Respiratory failure	Dead, 63 hrs.
Flexner 1916 - 18 c.c.		Increase of retraction. Constitutionally better.		
Flexner 1916 - 15 c.c.		Wandering.		
Flexner 1916 - 20 c.c.	IV	Good improvement	Streptococcal Meningitis	Dead
Flexner 1916 - 20 c.c.		General improvement.		
Flexner 1916 - 15 c.c.		No symptoms		
Flexner 1916 - 20 c.c.		Irritable, but bright		
Flexner 1916 - 15 c.c.		Comfortable.		
No serum				
Flexner 1916 - 20 c.c.	II	Respiratory failure restored by artificial respiration. Regained sensibility and general improvement.	None	Duty
Flexner 1916 - 20 c.c.		Disappearance of all symptoms		
Flexner 1916 - 20 c.c.	IV	Immediate recovery	None	Duty.
Flexner 1916 - 20 c.c.	—	Immediate recovery	None	Duty.
Flexner 1916 - 20 c.c.	I	Slight improvement, followed by good improvement	Intracranial pressure	Dead.
Flexner 1916 - 20 c.c.		Good improvement		
Flexner 1916 - 16 c.c.		Quite rational		
Flexner 1916 - 17 c.c.		Nystagmus, and jumpy.		
No serum		Quieter.		
Flexner 1916 - 18 c.c.		Hysterical. Intracranial pressure		
No serum				

3. *Tabular Statement of Symptoms*

Case and Age.	Date of Onset.	Date of Admission.	Condition of Consciousness.	Nuchal Muscular Spasm: Rigor.	Nuchal Muscular Spasm: Nature.	Reflex.	Dates of Lumbar Punctures.	Results of Spinal Fluid Examination.
20. 19 years.	Feb. 8	Feb. 8	Unconscious; Roaring.	+	Retraction.	+	Feb. 8	Very Turbid.
							Feb. 10	Very Turbid.
21. 20 years.	Feb. 8	Feb. 8	Retained Headache.	+	Stiff.		Feb. 8	Turbid.
							Feb. 9	Turbid.
							Feb. 14	Turbid.
							Feb. 17	Clear.
							Feb. 22	Opalescent.
							Feb. 24	Clear.
							Feb. [illegible]	Clear.
							Mar. 2	Clear.
							Mar. 4	Clear.
22. 16 years.	Feb. 13	Feb. 15	Semi-conscious. Hysterical.		Retraction.		Feb. 15	Very Turbid.
							Feb. 21	Clear.
23. 18 years.	Feb. 15	Feb. 15	Semi-conscious.		Retraction.		Feb. 15	Opalescent.
							Feb. 17	Opalescent.
24. 19 years.	Feb. 19	Feb. 19	Drowsy.		Stiff.		Feb. 19	Turbid.
							Feb. 23	Turbid.
25. 18 years.	Feb. 18	Feb. 19	Semi-conscious.		Stiff.		Feb. 19	Opalescent.
							Feb. 20	Turbid.
							Feb. 23	Very Turbid.
26. 18 years.	Feb. 19	Feb. 19	Comatose; Violent.	+	Retraction.	+	Feb. 19	Turbid.
							Feb. 21	Turbid.
							Feb. 28	Opalescent.
							Mar. 1	Turbid.
27. 24 years.	Feb. 19	Feb. 19	Unconscious.		Retraction.	+	Feb. 19	Opalescent.
							Feb. [illegible]	Turbid.

and Treatment. 1916-1917 *Series*—continued.

Serum and Dose	Type (Gordon)	Remarks on Progress	Complications.	Result.
Flexner 1916 — 20 c.c.	i	Became rational, but dull.		Dead.
Flexner 1916 — 20 c.c.		Stertorous.		
Flexner 1916 — 20 c.c.	ii		This man had a laparotomy performed on the day of admission, previous to coming under our observation. Later developed intracranial pressure and wasted.	Dead.
Flexner 1916 — 20 c.c.		Some alleviation of symptoms.		
Flexner 1916 — 20 c.c.		Lethargic.		
Flexner 1916 — 20 c.c.				
Flexner 1916 — 20 c.c.		Incontinent.		
No serum.		Noisy. Intracranial pressure.		
No serum.		Mental condition improved.		
No serum.		Cerebral irritation.		
No serum.				
Flexner 1916 — 20 c.c.	i	Good improvement.	None.	Duty.
Flexner 1916 — 20 c.c.		No further symptoms.		
Flexner 1916 — 18 c.c.	i		Acute Synovitis, right knee, on 5th day.	Duty.
Flexner 1916 — 20 c.c.		Cessation of Cerebro-Spinal Meningitis symptoms.		
Flexner 1916 — 20 c.c.	i	Improvement. Still dull.	None.	Duty.
Flexner 1916 — 20 c.c.		Cessation of symptoms.		
Flexner 1916 — 20 c.c.	ii	Improvement.	None.	Duty.
Flexner 1916 — 20 c.c.		Delirious.		
Flexner 1916 — 20 c.c.		Immediate recovery.		
Flexner 1916 — 20 c.c.	iv	Immediate improvement.	None.	Duty.
Flexner 1916 — 20 c.c.		Mental condition improved.		
Flexner 1916 — 20 c.c.		Developed symptoms of intracranial pressure.		
No serum.		Immediate recovery.		
Flexner 1916 — 20 c.c.	i	Regained consciousness.	None.	Duty.
Flexner 1916 — 20 c.c.		No further symptoms.		

3 *Tabular Statement of Symptoms*

Case and Age	Date of Onset	Date of Admission	General Condition	Nervous System	Muscular System	Reflexes	Urine	Special Points
28 21 years	Feb. 17	Feb. 17	Headache		Stiff		Feb. 17	Clear
							Feb. 21	Opalescent
							Mar. 7	Clear
							Mar. 9	Opalescent
							Mar. 17	Clear
29 18 years	Feb. 21	Feb. 22	Severe headache		Rigidity		Feb. 22	Opalescent
							Feb. 26	Clear
							Feb. 28	Very Turbid
							Feb. 29	Clear
30 40 years	Feb. 22	Feb. 26	Lateral Headache		Stiff		Feb. 26	Opalescent
					Stiff		Mar. 2	Opalescent
							Mar. 4	Clear
			Headache				Mar. 16	Clear
							Mar. 19	Turbid
31 18 years	Mar. 3	Mar. 4	Mentality dull. Collapsed		Rigidity		Mar. 4	Opalescent Very Low
			Retracted head and lethargic throughout				Mar. 6	Very Turbid
							Mar. 7	Turbid
							Mar. 9	Opalescent
							Mar. 11	Clear
							Mar. 11	Turbid
							Mar. 12	Opalescent
							Mar. 14	Opalescent
							Mar. 18	
							Mar. 20	Strongly Acid
							Mar. 21	Very Turbid
							Mar. 27	
							Mar. 30	Clear
							April 2	Clear

and Treatment. 1916-1917 *Series*—continued.

Serum and Dose.	Type (Gordon).	Remarks on Progress.	Complications.	Result.
Flexner 1916 — 16 c.c.	IV	Temperature dropped.	Left Irido-Cyclitis; Haemorrhagic rash; Cutaneous ulcers.	Loss of left eye. Invalided.
Flexner 1916 — 20 c.c.				
No serum.		Quite rational; no cerebro-spinal meningitis symptoms.		
No serum.		Very septic generally.	Right Otitis Media	
Flexner 1916 — 20 c.c.		Incontinent and wasting rapidly. Suddenly made good progress.	Right Mastoiditis.	
Flexner 1916 — 20 c.c.	I	Lethargic	None	Duty.
Flexner 1916 — 20 c.c.		Conscious, but incontinent.		
Flexner 1916 — 20 c.c.		Mental improvement, but incontinent.		
Flexner 1916 — 20 c.c.		Immediate recovery.		
Flexner 1916 — 20 c.c.	II	Cessation of all symptoms	None	Duty.
Flexner 1916 — 20 c.c.		Alleviation of symptoms.		
Flexner 1916 — 20 c.c.		Again alleviation.		
No serum.				
Flexner 1916 — 20 c.c.		Cessation of all symptoms.		
Flexner 1916 — 20 c.c.	I		Broncho-pneumonia.	Dead.
Flexner 1916 — 20 c.c.		Hydrocephalus.		
Flexner 1916 — 20 c.c.				
Flexner 1916 — 20 c.c.		Increased intracranial pressure.		
No serum.				
No serum.		Symptoms relieved.		
Flexner 1916 — 20 c.c.		Intracranial pressure	Pleurisy	
No serum.				
No serum.			General wasting	
Mulford — 1A c.c.		Pressure relieved		
No serum.			Hydrocephalus	
No serum.		[illegible]		
No serum.		[illegible]		
Flexner 1916 — 20 c.c.		General wasting		

3. *Tabular Statement of Symptoms*

Case and Age	Date of Onset	Date of Admission	Condition on Coming In	Nature of Symptoms: Ivor	Nerve	Reads	Date of Last Entry	Condition Special Points
32. 18 years.	Mar. 3	Mar. 4	Semi-conscious	—	Stiff	+	Mar. 4	Lethal — 30 c.c.
							Mar. 5	Very Lethal — 25 c.c.
							Mar. 6	Yellow Day — 25 c.c.
33. 23 years.	Mar. 4	Mar. 5	Semi-conscious	—	Rigid	+	Mar. 5	Lethal — 15 c.c.
							Mar. 6	Lethal — 25 c.c.
							Mar. 7	Blood-stained — 25 c.c.
							Mar. 10	Blood-stained — 35 c.c.
							Mar. 12	Very Lethal — 35 c.c.
34. 17 years.	Mar. 5	Mar. 6	Semi-conscious	—	Rigid	+	Mar. 6	Opalescent — 30 c.c.
							Mar. 8	Clear — 15 c.c.
							Mar. 10	Lethal — 40 c.c.
							Mar. 11	Lethal — 30 c.c.
35. 20 years.	Mar. 6	Mar. 7	Quite conscious	—	Stiff	+	Mar. 7	Opalescent — 30 c.c.
							Mar. 8	Blood-tainted — 18 c.c.
							Mar. 12	Lethal — 7 c.c.
			Headache				Mar. 18	Clear — 0 c.c.
			Unconscious				Apr. 2	Opalescent — 40 c.c.
							Apr. 3	Yellow Day — 25 c.c.
							Apr. 4	Clearer — 20 c.c.
36. 18 years.	Mar. 12	Mar. 12	Comatose, very Violent.	—	Retraction	+	Mar. 12	Lethal — 30 c.c.
							Mar. 13	Very Lethal — 25 c.c.
							Mar. 14	Lethal — 15 c.c.
							Mar. 15	Clearer — 5 c.c.
							Mar. 18	Fatal — 30 c.c.
							Mar. 21	Clearer — 25 c.c.
							Apr. 4	Opalescent — 15 c.c.
							Apr. 9	Clear — 2 c.c.
							Apr. 13	Opalescent — 20 c.c.
							Apr. 17	Yellow — 5 c.c.

and Treatment. 1916-1917 *Series*—continued.

Serum and Dose.	Type (Gordon).	Remarks on Progress.	Complications.	Result.
Flexner 1916 + 20 c.c.	Atypical	Unchanged	———	Dead.
Flexner 1916 + 20 c.c.		Delirious.		
Flexner 1916 + 20 c.c.		Respiratory failure.		
Flexner 1916 + 20 c.c.	1	Improvement ...	Broncho-pneumonia.	Dead.
Flexner 1916 + 20 c.c.			Continuous Delirium.	
Flexner 1916 + 20 c.c.		Serum Synovitis.		
Flexner 1916 + 20 c.c.				
Flexner 1916 + 20 c.c.		Delirium.		
Flexner 1916 + 20 c.c.	II	Good improvement ...	Broncho-pneumonia.	Dead.
Flexner 1916 + 20 c.c.		Drowsy, but comfortable.		
Flexner 1916 + 20 c.c.		Delirious.		
Flexner 1916 + 20 c.c.		Broncho-pneumonia.		
Flexner 1916 + 20 c.c.	I		None	Duty.
Flexner 1916 + 20 c.c.		Good improvement ...		
Flexner 1916 + 15 c.c.		No symptoms.		
Flexner 1916 + 20 c.c.		No symptoms till April 2.		
Flexner 1916 + 20 c.c.		Became sensible		
Flexner 1916 + 20 c.c.		Developed intracranial pressure		
No serum		Rapid recovery		
Flexner 1916 + 20 c.c.	I	Became rational	Pericarditis.	Duty.
Serum [illegible] Lady			Broncho-pneumonia.	
Flexner 1916 + 20 c.c.		General improvement.		
Flexner 1916 + 20 c.c.		Much better		
Flexner 1916 + 20 c.c.		Developed Pericarditis		
No serum.		Developed intracranial pressure symptoms		
Flexner 1916 + 20 c.c.		Developed Broncho-pneumonia		
[illegible]		Improvement but developed [illegible]		
No serum		No [illegible] Dead		
Flexner 1916 + 20 c.c.		Improvement [illegible]		

3. *Tabular Statement of Symptoms*

Case and Age	Date of Observation	Date of Admission	Cerebro-Cerebellar Condition	Nuchal Muscular System: Kernig's Sign	Nuchal Muscular System: Neck	Pupils	Dates of Lumbar Puncture	Cerebro-Spinal Fluid: Characters and Deposit
37. 19 years	Mar. 14	Mar. 15	Rational	—	Stiff	—	Mar. 15	Clear — 1 c.c.
							Mar. 16	Clear — 20 c.c.
							Mar. 17	Turbid — 20 c.c.
38. 18 years	Mar. 16	Mar. 19	Rational	—	Stiff	—	Mar. 19	Turbid — 30 c.c.
							Mar. 20	Turbid — 32 c.c.
							Apr. 1	Clear — 30 c.c.
			Delirious	—		—	Apr. 3	Opalescent — 25 c.c.
			Clouded				Apr. 4	Turbid — 40 c.c.
							Apr. 6	Yellow — 50 c.c.
39. 18 years	Mar. 20	Mar. 21	Drowsy	—	Stiff	—	Mar. 21	Turbid — 35 c.c.
							Mar. 24	Turbid — 25 c.c.
40. 18 years.	Mar. 9	Mar. 10	Collapsed	—	Rigid	—	Mar. 10	Turbid — 30 c.c.
							Mar. 12	Opalescent — 25 c.c.
							Mar. 17	Clear — 28 c.c.
							Mar. 24	Turbid — 30 c.c.
							Mar. 29	Opalescent — 30 c.c.
41. 18 years	Mar. 31	Apr. 2	Comatose	—	Rigid	—	Apr. 2	Turbid — 30 c.c.
							Apr. 3	Opalescent — 25 c.c.
							Apr. 4	Opalescent — 20 c.c.
42. 18 years	Apr. 3	Apr. 5	Patient	—	Intense rigidity	—	Apr. 5	Turbid — 30 c.c.
							Apr. 6	Opalescent — 25 c.c.
							Apr. 7	Clear — 40 c.c.
43. 20 years	Apr. 4	Apr. 4	Delirious, then comatose	—	Rigidity	—	Apr. 4	Opalescent — 20 c.c.
							Apr. 5	Opalescent — 25 c.c.
							Apr. 7	Turbid — 15 c.c.
44. 18 years	Apr. 27	Apr. 28	Semi-comatose, Delirious	—	Stiff	—	Apr. 28	Turbid — 30 c.c.
							Apr. 29	Clear — 30 c.c.
							Apr. 30	Turbid — 25 c.c.

and Treatment. 1916-1917 *Series* continued.

Serum and Dose.	Type (Gordon).	Remarks on Progress.	Complications.	Result.
No serum.		Polymorphs, but no meningococci.	None ...	Duty.
Flexner 1916 — 20 c.c.		Good improvement.		
Flexner 1916 — 18 c.c.		Rapid convalescence.		
Flexner 1916 — 20 c.c.	II	No symptoms. Bronchitis	Intracranial pressure.	Dead.
Flexner 1916 — 20 c.c.		Few complaints.		
Flexner 1916 — 20 c.c.		No symptoms till April 5, became delirious.		
Flexner 1916 — 20 c.c.		Comatose.		
No serum.		Intracranial pressure symptoms.		
Flexner 1916 — 20 c.c.	I	Little change	None	Duty.
Flexner 1916 — 20 c.c.		Rapid improvement.		
Flexner 1916 — 20 c.c.	II	Good improvement	Pericarditis	Duty.
Flexner 1916 — 20 c.c.		Excellent improvement.		
Flexner 1916 — 20 c.c.		Developed Pericarditis.		
Flexner 1916 — 18 c.c.		No symptoms of cerebro-spinal meningitis		
Flexner 1916 — 18 c.c.		Gradual convalescence.		
Flexner 1916 — 20 c.c.	II	Improvement	Pericarditis	Duty.
Flexner 1916 — 20 c.c.				
Flexner 1916 — 20 c.c.		No symptoms		
Flexner 1916 — 20 c.c.	I	Became less rigid ...	None	Duty
Flexner 1916 — 20 c.c.				
Flexner 1917 — 18 c.c.		No further symptoms		
Flexner 1916 — 20 c.c.		No symptoms	None	Duty.
Flexner 1916 — 16 c.c.		Less rigidity		
Flexner 1916 — 10 c.c.		No further symptoms		
Flexner 1916 — 20 c.c.		Rapid improvement. No symptoms	None	Duty
Flexner 1916 — 20 c.c.		Good improvement		
Flexner 1917 — 20 c.c.		No further symptoms		

3. *Tabular Statement of Symptoms*

Case and Age	Date of Onset	Date of Admission	General Condition	Nervo-Muscular System: Kernig	Nervo-Muscular System: Neck	Teeth	Dates of Lumbar Puncture.	Cerebro-Spinal Fluid Condition and Depletion.
45 17 years.	Apl. 9	Apl. 11	Occipital Headache.	+	Retraction	—	Apl. 11	Turbid — 25 c.c.
							Apl. 12	Very Turbid 25 c.c.
							Apl. 13	Cleaner 30 c.c.
				+	Stiff	—	Apl. 30	Turbid — 40 c.c.
							May 1	Opalescent 40 c.c.
							May 6	Opalescent 38 c.c.
46 53 years.	Apl. 30	May 1	Dull and Morose	+	Stiff	—	May 1	Turbid Yellow 27 c.c.
							May 2	Very Yellow 30 c.c.
							May 3	Yellow — 5 c.c.
							May 4	Cleaner — 25 c.c.
							May 7	Clear Yellow 20 c.c.
47 18 years.	May 28	May 28	Unconscious. Irritable.	+	Nil	—	May 28	Turbid Yellow 40 c.c.
							May 29	Very Turbid 30 c.c.
							May 30	Very Turbid — 35 c.c.
							May 31	Less Turbid 25 c.c.
48 29 years.	June 6	June 8	Headache only	+	Stiff	—	June 8	Turbid Yellow 35 c.c.
							June 9	Cleaner Yellow 31 c.c.
							June 10	Clear 25 c.c.
49 38 years.	June 23	June 24	Semi-comatose	+	Stiff	—	June 24	Turbid Yellow 30 c.c.
							June 25	Yellow — 25 c.c.
							June 26	Clear Yellow — 35 c.c.
							June 28	Clear — 40 c.c.

and Treatment. 1916-1917 *Series*- continued.

Serum and Dose.	Type (Gordon).	Remarks on Progress.	Complications.	Result.
Flexner 1916 20 c.c.	I	Less retraction	None	Duty.
Flexner 1916 20 c.c.		Increased retraction.		
Flexner 1916 20 c.c.		All symptoms disappear. Relapse, April 30.		
Flexner 1917 20 c.c.				
Flexner 1917 20 c.c.		Kernig and vomiting.		
Flexner 1917 20 c.c.		Rapid convalescence.		
Flexner 1917 20 c.c.	IV		None	Duty.
Flexner 1917 20 c.c.		Quiet, but not rational		
Flexner 1917 10 c.c.				
Flexner 1917 15 c.c.		Good improvement.		
Flexner 1917 15 c.c.		No further symptoms.		
Flexner 1917 20 c.c.	I	Mental improvement	None	Duty.
Flexner 1917 15 c.c.		Became rational.		
Flexner 1917 20 c.c.		Still morose.		
Flexner 1917 20 c.c.		No further symptoms.		
Flexner 1917 20 c.c.	I	Slight improvement	None	Duty.
Flexner 1917 20 c.c.				
Flexner 1917 20 c.c.		No further symptoms.		
Flexner 1917 20 c.c.	III	No stiffness of neck	Serum Synovitis	Duty.
Flexner 1917 20 c.c.		Good improvement.		
Flexner 1917 20 c.c.		Cerebral symptoms gone		
Flexner 1917 20 c.c.				

4 *Notes on Individual Cases.*

(Laboratory of the Lunacy Statistical and Investigation Staff.)

Case 1.—Requires no comment.

Case 2.—Had been under observation nine days outside previous to admission. The disease ended by crisis and rapid convalescence after the fourth injection.

Case 3.—Requires no comment.

Case 4.—A fulminating case who died in twenty-eight hours.

First lumbar puncture was performed under scopolomorphine, but as he was rather restless and little cerebro-spinal fluid was obtained a general anæsthetic was used for the second operation.

He developed respiratory failure thirty minutes after completion of lumbar puncture, was restored by artificial respiration, but developed a second attack of respiratory failure three hours later and died.

The error committed here was undoubtedly the injection of a large dose of serum after little cerebro-spinal fluid had been obtained. The respiratory failure is thought to have been in no way due to the anæsthetic.

Case 5.—A very severe case.

The first two lumbar punctures were performed under scopolomorphine, but as the man was very violent the last three were performed under general anæsthesia.

His convalescence after the seventh day was delayed by a very profuse serum rash and constitutional disturbance which accounted for the continuation of his pyrexia. Following his fifth injection of serum his mental condition became quite normal and no anxiety was felt about him, his chart being no criterion of his condition.

On the sixteenth day he developed rubella.

Case 6.—A severe case necessitating, on account of violence, the administration of a general anæsthetic. Although his condition after treatment had improved considerably and he had become rational, he died three and a half hours after third injection from sudden heart failure.

Case 7.—A fulminating case who died in twenty-three hours.

There was no reaction to two lumbar punctures and injection of serum.

Case 8.—Showed good improvement after each operation but required four lumbar punctures and injection of serum.

His mental condition also was complicated by delirium tremens.

After the seventh day, having previously caused much anxiety, he made an excellent recovery, but was invalided on account of age.

Case 9.—No comment.

Case 10.—No comment.

Case 11.—A dramatic cure of cerebral and spinal symptoms, but he developed suppurative endocystitis of the left eye on the sixth day. Loss of vitreous caused the destruction of vision and necessitated enucleation.

He made an excellent constitutional recovery, but was invalided on account of the loss of the eye.

Case 12.—A very severe case, violent and resisting, necessitating the administration of a general anæsthetic on the first occasion of lumbar puncture. He improved considerably mentally but developed bronchitis of a very severe type, finishing the clinical course by death in eighty-seven hours.

Case 13.—A fulminating case with a large amount of moisture in the lungs from the outset. He died in sixty-seven hours.

Case 14.—Showed some improvement following treatment, but died in sixty-three hours of sudden respiratory failure.

Case 15.—Illustrates a type of case in which error was committed in not persisting in further serum treatment in view of the continued pyrexia. A mild case from the beginning; after primary treatment he presented no subjective symptoms and few signs.

Expectant treatment was carried out until the thirty-fourth day, when he became unconscious and died.

At the final lumbar puncture streptococci were found in the cerebro-spinal fluid.

This is the only case in which secondary infection occurred, and it does not necessarily represent an accident due to lumbar puncture.

Case 16.—No comment.

Case 17.—No comment.

Case 18.—This man had been ill three days previous to admission.

His signs and symptoms were definitely those of cerebro-spinal meningitis, except that he presented no rash.

His cerebro-spinal fluid was opalescent and contained pus cells, but no organism was certainly demonstrated.

Since only one lumbar puncture and dose of serum affected a cure, the laboratory had no further opportunity of obtaining fluid for investigation.

Case 19.—This case improved in the early stages, but later injections of serum caused the development of intracranial pressure. This was treated by lumbar puncture alone. He died after seventeen days, the cause being increasing intracranial pressure.

Case 20.—A fulminating case reacting slightly to treatment.

Case 21.—This case was taken over from the surgical side of the hospital, a laparotomy having been performed on account of his condition being mistaken for perforated gastric ulcer.

He corresponds very much to Case 15, and the same error was committed—failure to persist in serum treatment in the early stages.

He improved a little to begin with, and, in view of his surgical condition, expectant treatment was carried out until it was too late. Following his fifth injection of serum on the fifteenth day he developed intracranial pressure and wasting, necessitating frequent lumbar puncture alone, which had no effect on his condition.

Case 22.—No comment.

Case 23.—This case presented no active signs of cerebro-spinal meningitis after the fourth day.

The continuation of pyrexia was due to a very acute synovitis of the right knee joint, thought to be caused by serum.

Case 24.—No comment.

Case 25.—No comment.

Case 26.—The most acutely ill of any case received.

He was comatose, cyanosed and pulseless, with incontinence of urine and fæces. It was at first thought that he would not live long enough for lumbar puncture to be performed.

[illegible] were [illegible] before the first twelve hours following primary treatment was particularly dramatic and after forty-eight hours he had no complaints.

Circumstances in private forced us to give serial cases on the tenth day, curing but to develop intraspinal pressure which was relieved by one further injection of serum spinal fluid. His convalescence and ultimate recovery were excellent.

Case 27.—No comment.

Case 28.—A very fine case.

She was in the sixth day of rubella when he developed hyperpyrexia and [illegible] cerebro-spinal meningitis. Her purpuric rash was very [illegible].

The clinical symptoms were so definite at first lumbar puncture that, in spite of the cerebro-spinal fluid being clear, he was given 20 c.c. of serum. The result was most dramatic and lasted to just over. All cerebro-spinal symptoms disappeared with the exception of the rash, which increased, became hemorrhagic, then vesicular and finally pustular.

The recovery appears in the earlier cases that was expected.

On the 26th day he developed suppurative iridocyclitis of the left eye. Second lumbar puncture was immediately performed and a further 20 c.c. of serum given. On the second couple of days the laboratory report was positive.

With this secondary rise of temperature he had no signs of cerebro-spinal meningitis except the eye condition, which drew visual [illegible] on the pyrexia, but he was thought to be an instance of [illegible] and spinal symptoms gone.

Further complications developed [illegible] a mixed mode of a very bad type, streptococcal aleuritica where pustulation of the rash had occurred, and general [illegible] of the skin of the trunk. He became very septic and wasted considerably.

In the absence of cerebral and spinal symptoms and in view of our previous experience of injecting serum into the disease, such treatment was not employed.

Anti-streptococcal serum was given intravenously, but beyond [illegible] it was [illegible] was carried out.

Lumbar puncture without injection of serum was performed on two occasions for information.

On the twenty-eighth day complications having been alleviated, but he remains still wasting and running a septic, it was decided to risk intraspinal pressure by giving serum again. At this time he was very exhausted but quite bright mentally and taking all food well.

Following the last injection of serum he began to put on flesh rapidly, and within a month was strong enough to be transferred to the surgical section for radical treatment of the otitis media. The sight of the left eye was not completely lost, but he was invalided from the service on account of the [illegible] disability of ear and eye.

Case 29.—[illegible] comment.

Case 30.—A mild case throughout, and although not admitted until the fifth day of its disease he reacted well to first treatment.

Subsequent rises of temperature were treated by lumbar puncture.

His cerebral and spinal symptoms were so mild or absent that the condition never gave rise to anxiety.

Case 31.—A peculiar case in many aspects. He was not seen much earlier on treatment, both early and late in the disease, but never reacted and he developed intraspinal pressure in the second week.

A great point of interest was that the patient, owing to an accident in childhood, had an area of bone about 2 in. in its extent missing at

the left temporal region. Through this opening a hernia cerebri used to form under the skin when intracranial pressure was present, and disappeared after depletion of the cerebro-spinal fluid

The hernia was accompanied by headache, vomiting, and muscular twitching of the limbs

Mulford serum was tried in the third week, but caused a very large increase in pressure and no beneficial result

In the last week of his illness pressure was absent, and instead of a hernia cerebri the skin of the scalp retracted within the skull as though the production of cerebro-spinal fluid had ceased and a vacuum was being formed within

Throughout his illness he showed few acute symptoms other than those mentioned. He was lethargic and at times irritable; always a voracious eater he was kept on a very liberal diet which he digested

Meningococci were present in the cerebro spinal fluid on all examinations.

Case 32.—A fulminating case who showed no improvement after treatment.

Meningococci were found in the first specimen of cerebro-spinal fluid, but the type was not capable of being identified with any of Gordon's

Case 33.—Improved well at the beginning of treatment, but developed broncho pneumonia and died in the third week

Case 34.—Made good progress during the first three days, and then developed broncho-pneumonia and died on the tenth day.

Case 35.—Demonstrates primary dramatic recovery with relapse on the sixth day

He relapsed again on the twenty seventh day and became comatose

Serum treatment was again applied with the immediate development of intracranial pressure which was relieved by one depletion of cerebro-spinal fluid. He made an uninterrupted recovery.

Case 36.—A very difficult case to treat and in which to assess the value of symptoms

He reacted well to serum at the outset cerebral and spinal symptoms disappearing.

Complications then supervened, viz pericarditis on the seventh day, synchronous with a serum rash; intracranial pressure on the tenth day, and broncho-pneumonia on the fourteenth day.

In the absence of cerebral and spinal symptoms, serum was not again employed until the twenty-fourth and twenty fifth day and all attention was directed towards the treatment of complications

This late serum treatment was immediately followed by incontinence of urine and feces which persisted until the forty first day. Pyrexia still being present the cerebro-spinal fluid was re-examined but meningococci could not be found although the fluid was still opalescent

Lumbar puncture was performed on the forty fifth day and 20 c.c. of serum injected the result was dramatic and a rapid convalescence was established.

This man returned to full duty

Case 37.—An undoubted case of cerebro spinal meningitis presenting all signs and a good rash, but a case in which the meningococcus was never demonstrated although the cerebro-spinal fluid contained a few polymorphonuclear cells

Case 38.—This case had been suffering from acute bronchitis since March 7th. He developed the first symptoms of cerebro spinal meningitis on March 16th and came under our observation on March 19th

His symptoms then were definite but of a mild type

These symptoms disappeared after one lumbar puncture and injection of serum, but the bronchitis remained and was thought to account for the pyrexia. He improved greatly until March 29th, when he again developed cerebral and spinal symptoms. These were treated by two injections of serum with good improvement which lasted until April 25th. He then developed intracranial pressure, became choreic and in spite of depletion of cerebro-spinal fluid, died.

A case illustrating how complications can mislead, and the dangers of serum administration late in the disease.

Case 39.—No comment.

Case 40.—Illustrating good results in the first week but complicated by pericarditis on the eighth day, which was judged to account for his temperature.

Further serum treatment was employed on the chance of the pericarditis being meningococcal in origin, but his condition never caused anxiety after the first week.

Case 41.—Reacted well to treatment; was quite convalescent when he developed pericarditis on the fourteenth day.

Case 42.—No comment.

Case 43.—No comment.

Case 44.—No comment.

Case 45.—Illustrating dramatic relief of the initial symptoms by very copious serum disease and albuminuria, and a relapse of cerebral and spinal symptoms in the third week. The latter recovered quite well to serum.

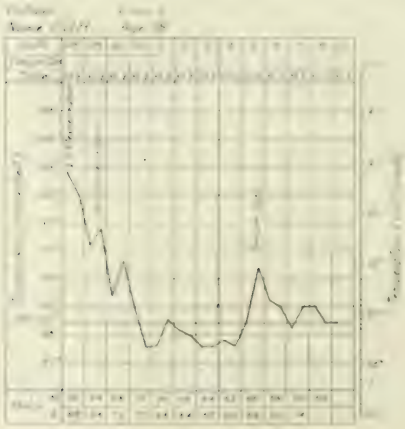
Case 46.—No comment.

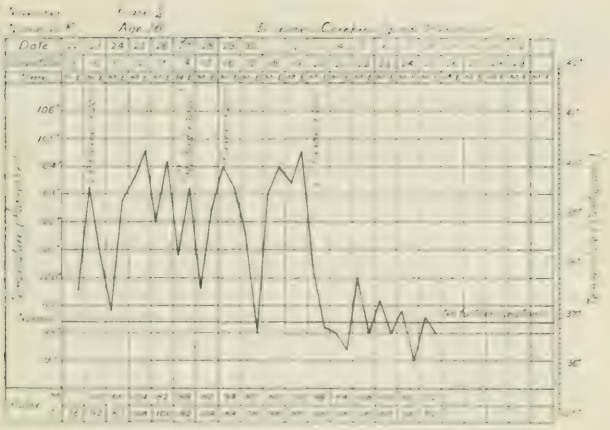
Case 47.—No comment.

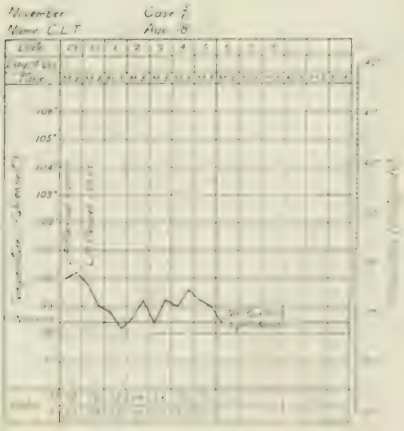
Case 48.—No comment.

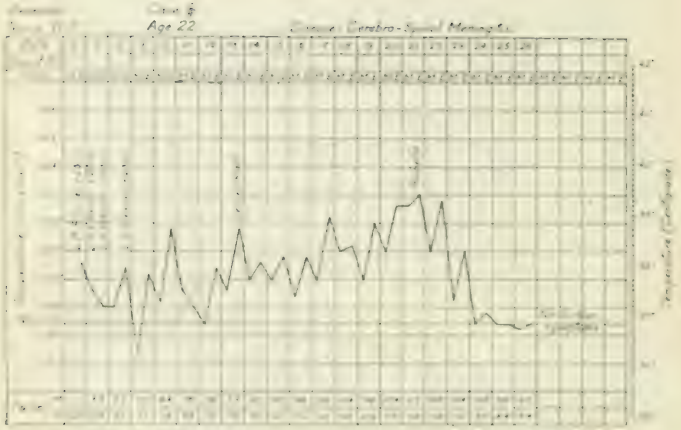
Case 49.—No comment.

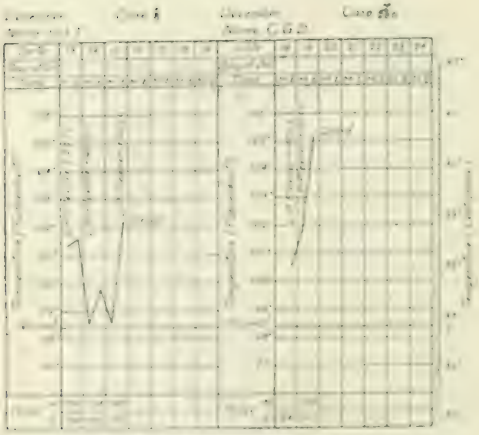
5. *Temperature Charts*—1916–1917 Series.

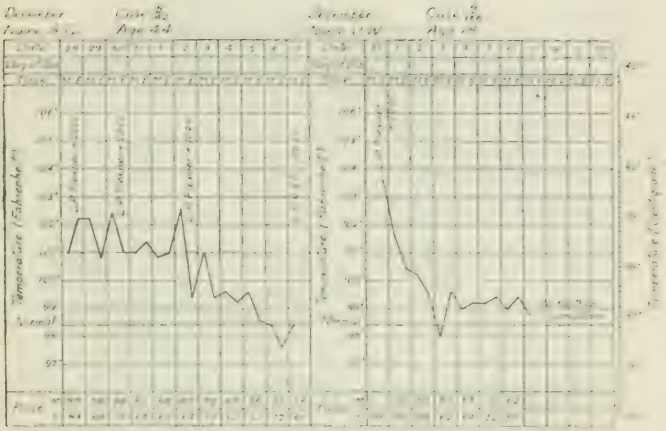


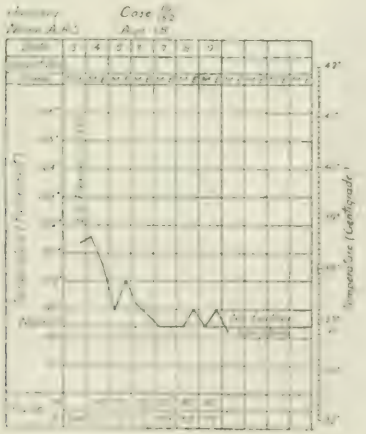


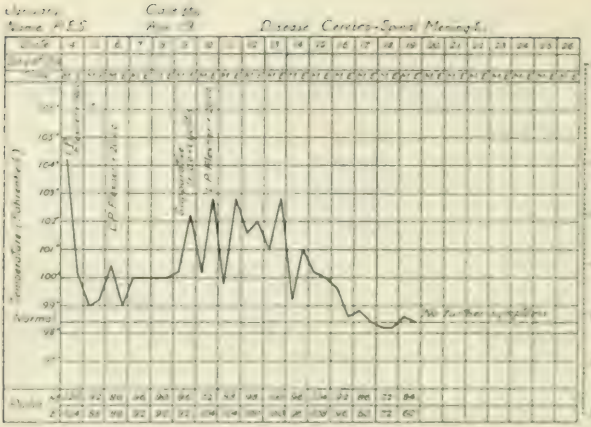


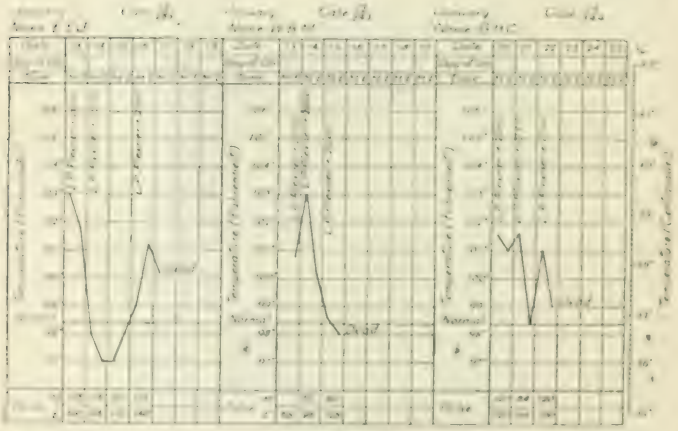


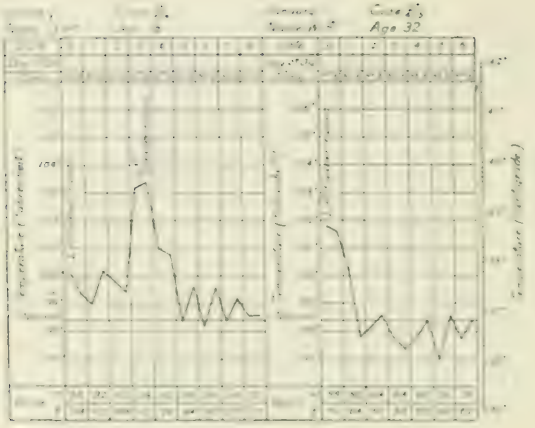


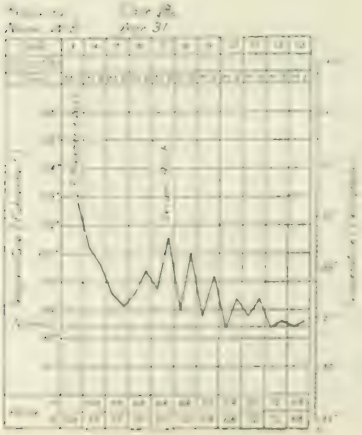


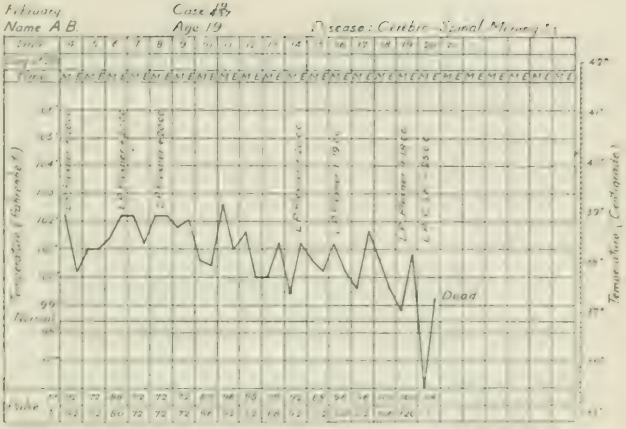


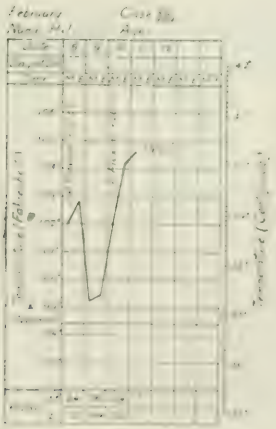

Disease Cerebro-Spinal Meningitis
Normal
No Perspiration
Temperature (Fahrenheit)
Temperature (Centigrade)

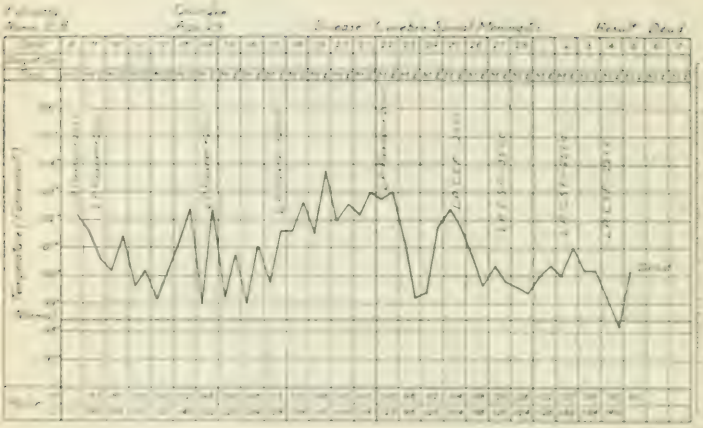


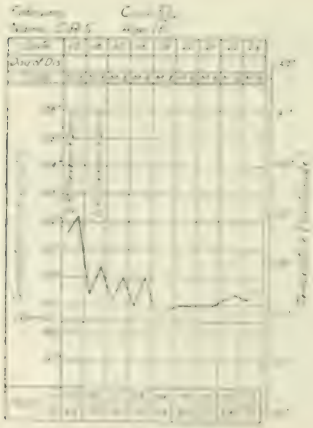


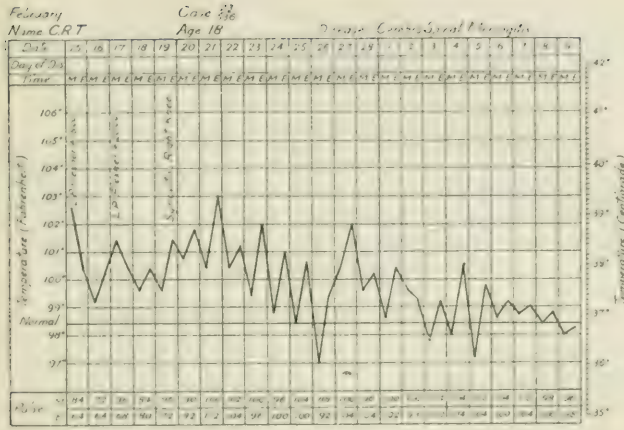


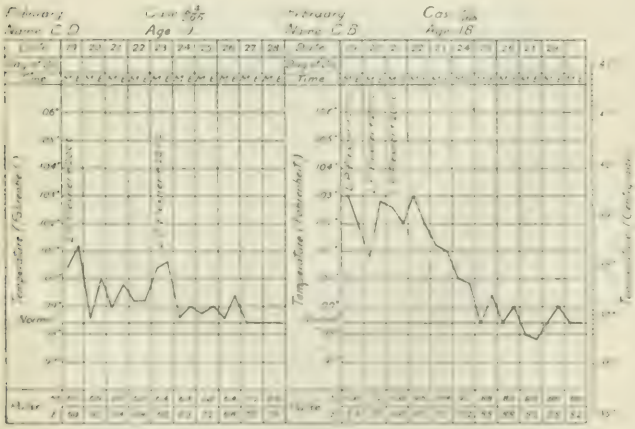

February
Name A B.
Case 48
Age 19
Disease: Cerebro-Spinal Menin
Dead

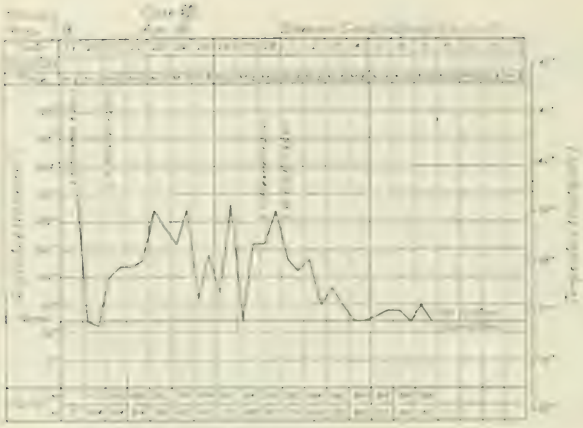

February

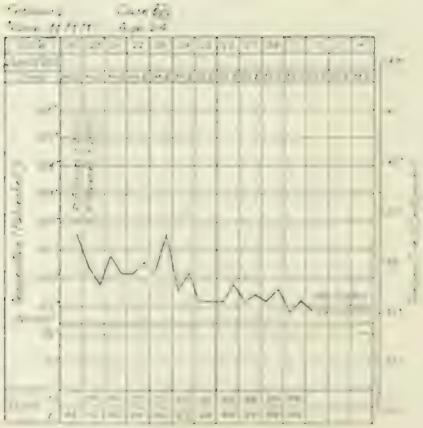


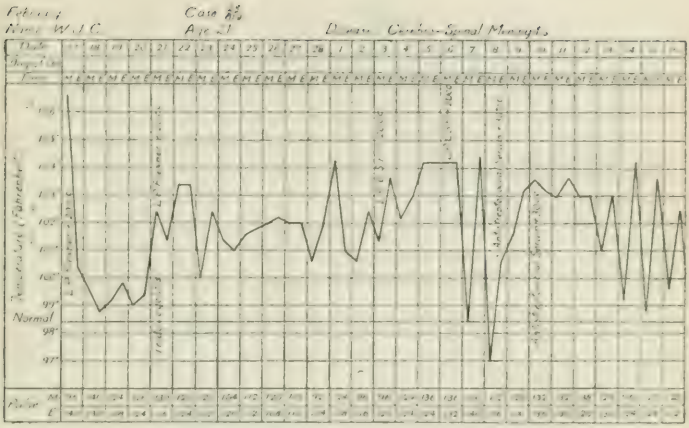



February
Name C R T
Case
Age 18
Temperature (Fahrenheit)
Temperature (Centigrade)
Normal
Pulse

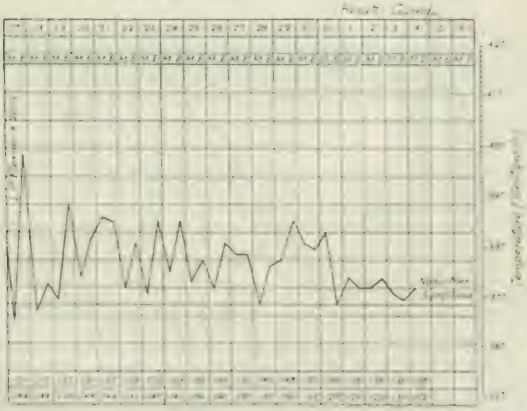

February
Name C D
Age 1
February
Name C B
Age 18
Temperature (Fahrenheit)
Normal
Pulse

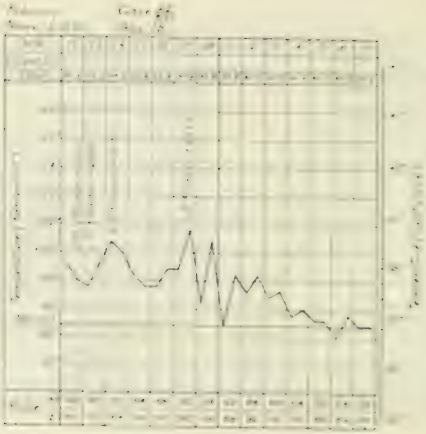


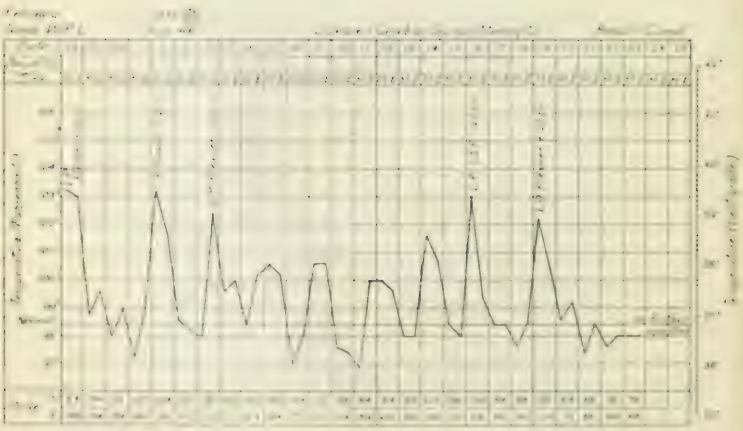




Case 8th continued







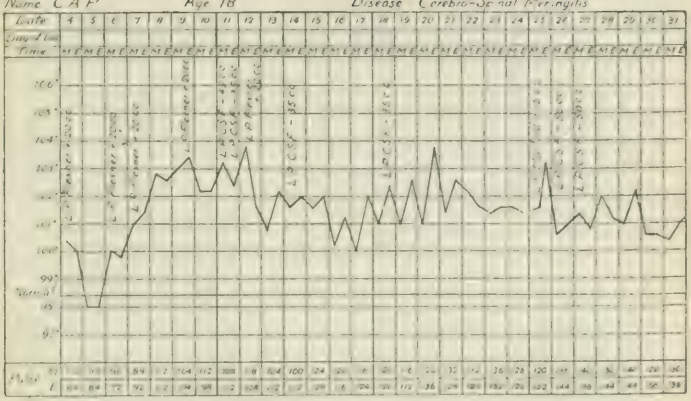
March

Case $\frac{31}{287}$

Name C A P

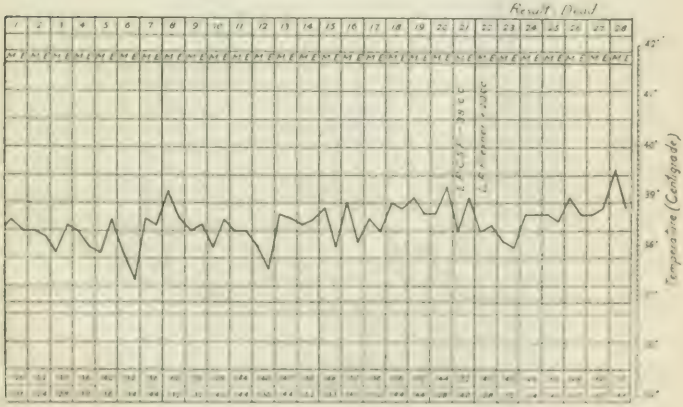
Age 18

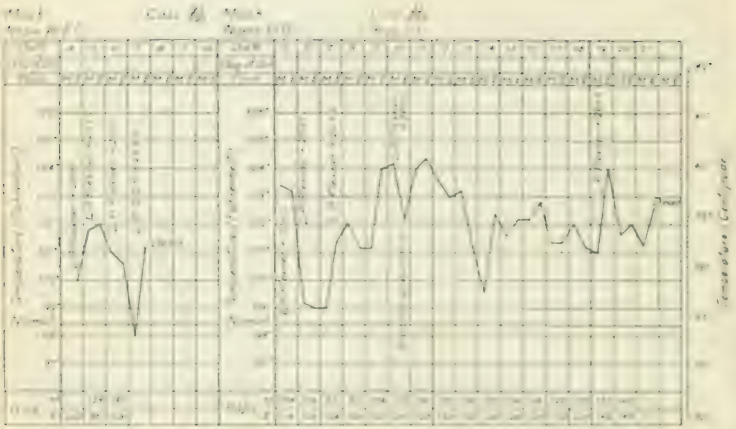
Disease Cerebro-Spinal Meningitis

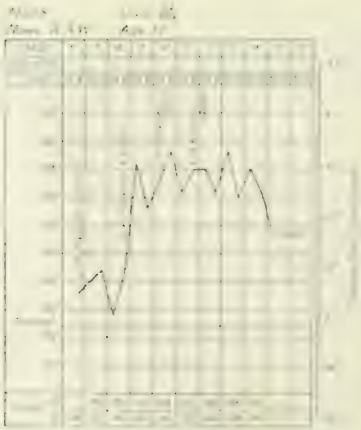


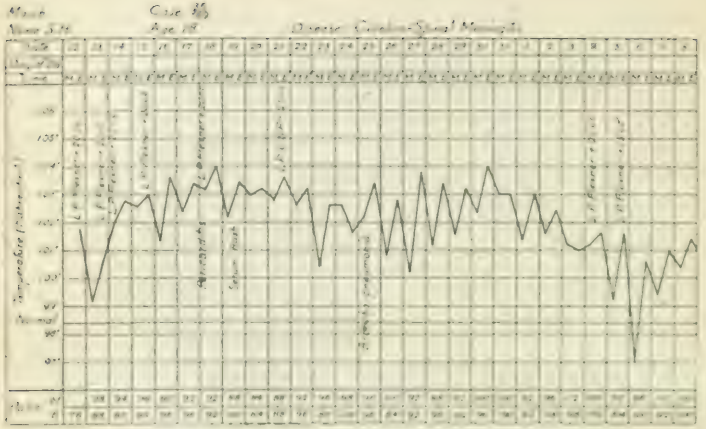
Case $\frac{31}{287}$ continued

Result Died

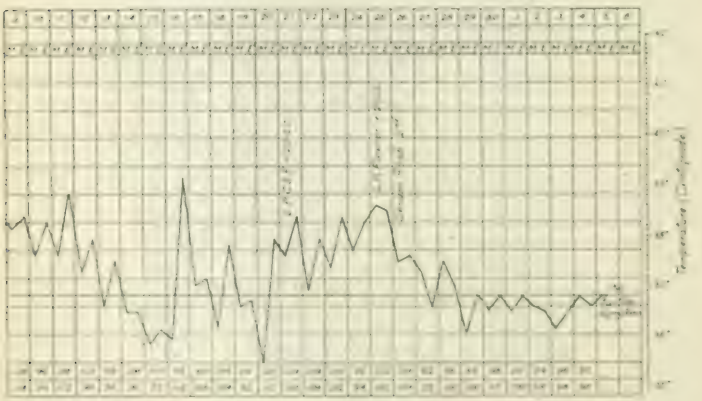


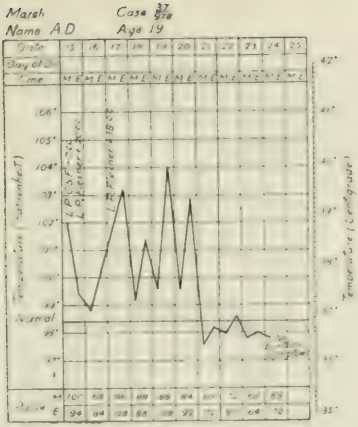


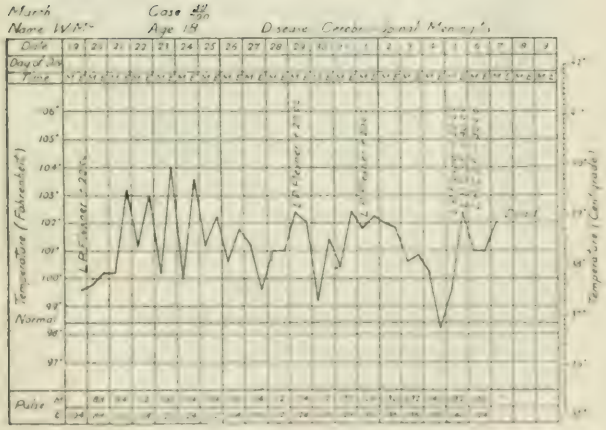


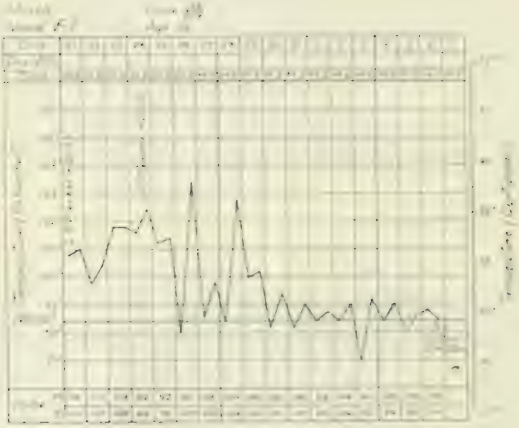


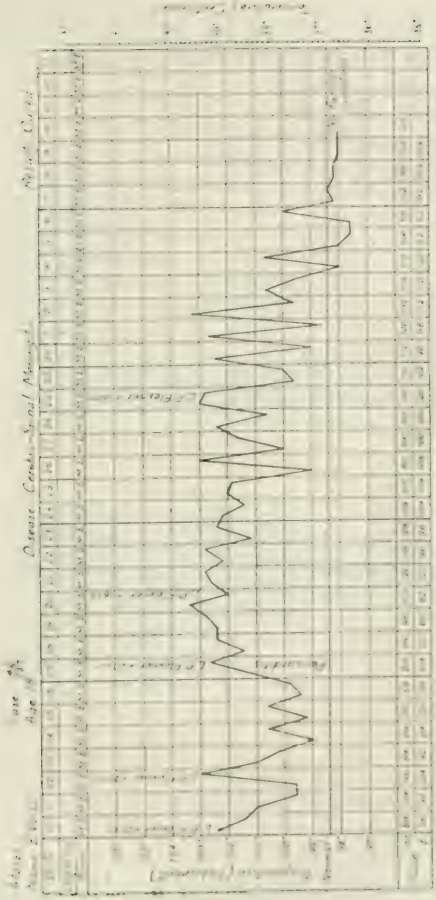
Case ⅓ continued

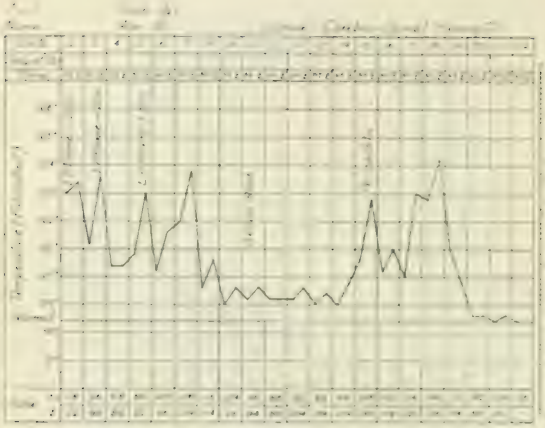


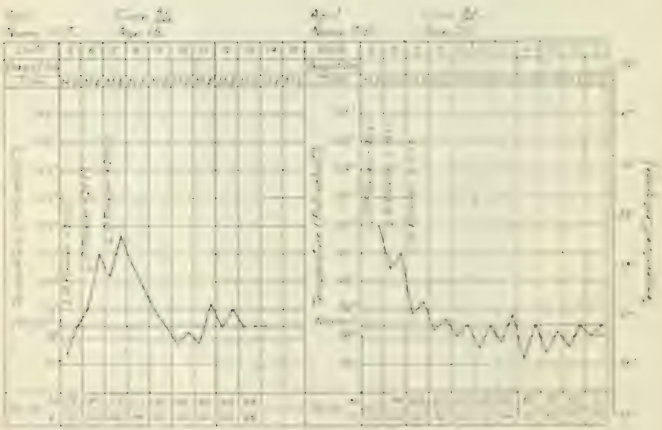

March
Case 37/170
Name A.D
Age 19
Date
Day of Dis.
Time
Temperature (Fahrenheit)
Temperature (Centigrade)
Normal
Pulse

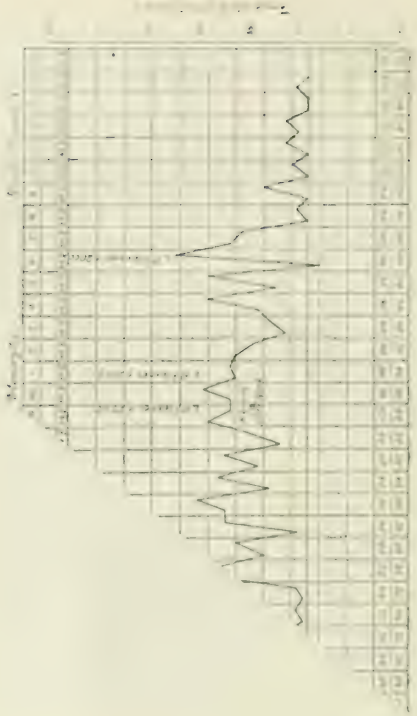

March
Case 41/170
Name W.N.-
Age 18
Disease Cerebro-spinal Meningitis
Date
Day of Dis.
Time
Temperature (Fahrenheit)
Temperature (Centigrade)
Normal
Pulse

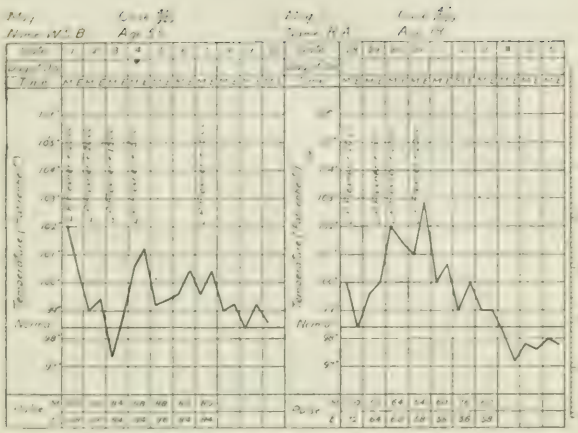


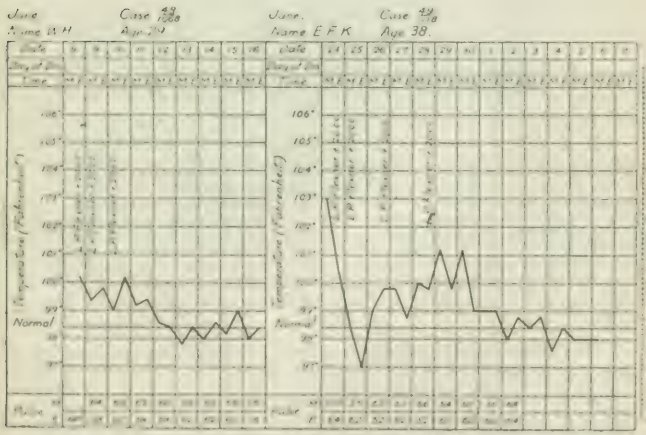









Name W. B
Name H A
Temperature (Fahrenheit)
Temperature (Centigrade)
Normal


June
Name W H
Age 24
Name E F K
Age 38.
Temperature (Fahrenheit)
Temperature (Centigrade)
Normal

6. *General Conclusions.*

It is important to be able to recognise whether secondary rises of temperature are due to the disease, the serum, or developing complications.

This is where the greatest errors will be made, and we are of opinion that they can best be avoided by—

(*a*) A knowledge of the results to be expected from serum treatment;

(*b*) Experience with which to judge correctly when an alteration in temperature indicates a complication due to the meningococcus.

The following facts have been noted:—

(1) In certain cases one injection of serum will cure the disease and cause crisis: illustrated in Cases B., C., J., P., S., V. (1915-1916), 1, 9, 10, 17, 18, 27 (1916-1917).

(2) Other cases demand further serum treatment, due to return of pyrexia and cerebral and spinal symptoms, viz., K., Q., U. (1915-1916), 11, 16, 22, 24, 30, 37 (1916-1917).

(3) That rise of temperature may follow serum injection well illustrated in Cases 15, 26, 42, 47.

Rise of temperature caused only by complications is shown in Cases N., 11, 18, 23, 41.

(4) That injection of serum late in the disease appears to cause intracranial pressure.

(5) That frequent lumbar puncture and depletion of cerebro-spinal fluid is conducive to wasting, slow convalescence, and sometimes death.

In spite of dramatic cures by crisis after one or more injections, in order to prevent (i) secondary pyrexia, (ii) the necessity of late serum treatment, and (iii) the unnecessary depletion of cerebro-spinal fluid, it appears to be advisable to aim at administering all injections of serum during the first week of treatment.

Incur the risk of over serum treatment rather than under treatment; the former is the lesser evil and more easily dealt with.

The awaiting of the re-development of symptoms and pyrexia is not only inadvisable but dangerous to life.

This method of semi-intensified treatment, even in cases showing dramatic recovery after first injection, was latterly carried out, and is illustrated in Cases 42, 43, 46, 47, 48 and 49.

All these cases had particularly rapid convalescences, free from all complications other than serum rashes and severe joints.

Three or four 20 c.c. doses on consecutive days are recommended. The giving of larger doses we did not find satisfactory; in fact we note that we only did so in cases which afterwards proved fatal, and these were no more severe clinically than cases which recovered under the 20 c.c. dose.

Regarding serious complications which may arise :—

(1) Suppurative irido-cyclitis, a known symptom of the disease, occurred in 2 cases.

(2) Pericarditis developed in 4 cases.

(3) Acute synovitis of the larger joints developed in 6 cases.

These two latter we regard as being due to serum, as they synchronise with some stage of the serum rash.

Of complications contributory to death :—

Broncho-pneumonia developed in 6 cases.

Heart failure was the cause of fatal termination in 4 cases.

Respiratory failure in 4 cases.

Secondary streptococcal infection of the meninges occurred in 1 case.

Intracranial pressure, demanding depletion of the cerebro-spinal fluid at frequent intervals, was answerable for death in the remaining 4 cases.

For the prevention of the development of pulmonary complications we are certain that the importance of continual attention to the cleanliness of the mouth, nose and throat of all cases, comatose or rational, cannot be exaggerated.

We are indebted to our nursing staff for their untiring efforts in carrying out this part of treatment, which we feel has been the means of preventing disaster.

Except for these, it will be noted that complications are few and *sequelæ* almost totally absent.

When one considers that out of 71 cases of a disease, which was formerly regarded with dread and often caused either death or the crippling of one or other of the senses, 19 only died, 5 were invalided, and 47 returned to full duty in H.M. Fleet, no mean form of labour, we think that the value of serum treatment is justly established.

APPENDIX.

Table of Cross References.

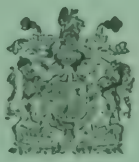
Between the cases described in the 1916–1917 series and the bacteriological account of Staff Surgeon Fildes and Surgeon Baker.

Clinical No.	Bacteriological No.	Clinical No.	Bacteriological No.
1	1	26	567
2	4	27	585
3	6	28	619
4	5	29	633
5	8	30	642
6	9	31	687
7	286	32	695
8	142	33	696
9	166	34	704
10	182	35	705
11	206	36	769
12	285	37	978
13	343	38	790
14	344	39	809
15	357	40	737
16	414	41	843
17	415	42	846
18	436	43	847
19	437	44	841
20	469	45	868
21	468	46	949
22	527	47	1,028
23	536	48	1,068
24	566	49	1,118
25	568		

NATIONAL HEALTH INSURANCE.

MEDICAL RESEARCH COMMITTEE.

An Investigation into the Epidemiology of Phthisis in Great Britain and Ireland.



LONDON
PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE

To be purchased directly or through any bookseller from
H.M. STATIONERY OFFICE at the following addresses:
Imperial House, Kingsway, London, W.C. 2, and 28, Abingdon Street,
London, S.W. 1
37, Peter Street, Manchester; 1, St. Andrew's Crescent, Cardiff
23, Forth Street, Edinburgh
or from E. PONSONBY, Ltd., 116, Grafton Street, Dublin

1919.

MEDICAL RESEARCH COMMITTEE.

The following publications relating to the work of the Medical Research Committee can be purchased through any bookseller or directly from H.M. Stationery Office at the following addresses: Imperial House, Kingsway, London, W.C. 2, and 28 Abingdon Street, London, S.W. 1; 37 Peter Street, Manchester; 1 St. Andrew's Crescent, Cardiff; 23 Forth Street, Edinburgh; or from E. Ponsonby, Ltd., 116 Grafton Street, Dublin.

First Annual Report of the Medical Research Committee, 1914-1915 [Cd. 8101.] Price 3d., post free 4d.

Second Annual Report of the Medical Research Committee, 1915-1916 [Cd. 8399.] Price 3½d., post free 5d.

Third Annual Report of the Medical Research Committee. [Cd. 8825.] Price 6d., post free 7d.

Special Report Series.

No. 1. First Report of the Special Investigation Committee upon the Incidence of Phthisis in relation to Occupations.—The Boot and Shoe Trade. Price 3d., post free 4d.

No. 2. Report of the Special Advisory Committee upon Bacteriological Studies of Cerebro-spinal Fever during the Epidemic of 1915. Price 6d., post free 7d.

No. 3. Bacteriological Studies in the Pathology and Preventive Control of Cerebro-spinal Fever among the Forces during 1915 and 1916. Price 1s. 6d., post free 1s. 8d.

No. 4. Reports upon Investigations in the United Kingdom of Dysentery cases received from the Eastern Mediterranean.

I. Amœbic Dysentery and the Protozoological Investigation of Cases and Carriers. Price 1s., post free 1s. 2d.

No. 5. II. Report upon 878 Cases of Bacillary Enteritis. Price 1s. 6d., post free 1s. 8d.

No. 6. III. Report upon Recovered Cases of Intestinal Disease in the Royal Naval Hospital, Haslar, 1915-16.

IV. Report upon combined Clinical and Bacteriological Studies of Dysentery Cases from the Mediterranean. Price 1s. 6d., post free 1s. 8d.

No. 7. V. Report upon 2,360 Enteritis "Convalescents" received at Liverpool from various Expeditionary Forces. Price 2s., post free 2s. 2d.

No. 8. Report upon Soldiers returned as Cases of "Disordered Action of the Heart" (D.A.H.) or "Valvular Disease of the Heart" (V.D.H.). Price 1s., post free 1s. 2d.

No. 9. A Report upon the use of Atropine as a Diagnostic Agent in Typhoid Infections. Price 1s., post free 1s. 2d.

No. 10. The Mortalities of Birth, Infancy, and Childhood. Price 1s. 6d., post free 1s. 8d.

No. 11. The Causation and Prevention of Tri-nitro-toluene (T.N.T.) Poisoning. Price 1s., post free 1s. 2d.

No. 12. The Classification and Study of the Anaerobic Bacteria of War Wounds. Price 2s., post free 2s. 2d.

No. 13. An Enquiry into the Composition of Dietaries, with Special Reference to the Dietaries of Munition Workers. Price 3d., post free 4d.

No. 14. Reports of the Special Committee upon the Standardization of Pathological Methods.

No. 1. The Wassermann Test. Price 3d., post free 4d.

No. 15. A Study of 1,300 Convalescent Cases of Dysentery from Home Hospitals, with special reference to the Incidence and Treatment of Acute Dysentery Carriers. Price 6d., post free 7d.

No. 16. A Report on the Causes of Wastage of Labour in Munition Factories. Price 1s. 6d., post free 1s. 8d.

No. 17. I. A Report upon the Seasonal Outbreak of Cerebro-spinal Fever in the Navy at Portsmouth, 1916-1917.

II. The treatment of Cerebro-spinal Meningitis by Anti-meningococcus serum at the Royal Naval Hospital, Haslar, 1915-16-17. Price 2s. 6d., post free 2s. 9d.

No. 18. An Investigation into the Epidemiology of Phthisis in Great Britain and Ireland. Price 1s. 3d., post free 1s. 5d.

The following is published under the direction of the Medical Research Committee by Messrs. Longmans, Green & Co., 39 Paternoster Row, London, E.C.:

Milk and its Hygienic Relations. By Janet E. Lane Claypon, M.D., D.Sc., Lond. Price 7s. 6d. net.

NATIONAL HEALTH INSURANCE.

MEDICAL RESEARCH COMMITTEE.

An Investigation into the Epidemiology of Phthisis in Great Britain and Ireland.

(*Approved for publication by the Medical Research Committee, 12th October, 1917.*)

Medical Research Committee.

(National Health Insurance.)

The Hon. Waldorf Astor, M.P. *(Chairman).*

The Right Hon. Christopher Addison, M.D., M.P.

The Viscount Goschen, C.B.E. *(Treasurer)*

C. J. Bond, C.M.G., F.R.C.S. (Hon. Colonel).

A. K. Chalmers, M.D., D.P.H. (Lieut.-Colonel R.A.M.C. (T.)).

Professor William Bulloch, M.D., F.R.S.

Professor F. G. Hopkins, D.Sc., F.R.S.

Colonel Sir William Leishman, K.C.M.G., C.B., F.R.S.

Professor G. R. Murray, M.D., F.R.C.P. (Major R.A.M.C. (T.)).

Sir Walter M. Fletcher, K.B.E., M.D., F.R.S. *Secretary.*

15, Buckingham Street,
Strand, W.C. 2.

Wt. [illegible] 818 **Gp. 32**

INTRODUCTION.

In June, 1916, Dr. Brownlee published in "Public Health" a preliminary account of his work upon the Registrar-General's returns of mortality from phthisis, in which he showed that the results of his statistical analysis offered features of novelty and great interest. They gave evidence that phthisis is a disease not of single type, but of at least two and perhaps of three types, distinguished by the characters of their incidence at different ages of life. One type attacks chiefly the young adult, the commonest age of death lying between 20 and 25 years; a second has its incidence at middle age, killing most commonly between 45 and 50, while a third type, less certainly to be distinguished, belongs to old age, with its deaths falling chiefly between 55 and 65. These types of phthisis in the British Islands are found to have different geographical distributions which may be detected by the separate analyses of the mortality returns for particular regions.

The statistical enquiries from which these results have emerged are now presented more completely here, and the results are more fully discussed in their bearing upon the epidemiology of phthisis. To the analysis of the Registrar General's returns since 1850 given in Part I there is added in Part II of this Report a review of the available historical *data* of mortality due to phthisis from the 17th century to the present era of registration, with an examination of the evidence they give to show the ebb and flow of the phthisis mortality through successive decades.

The interest and importance of Dr. Brownlee's conclusions for other fields of enquiry are manifest; they carry obvious suggestions for research in the directions from which their confirmation has to be awaited. The results of clinical observation as such have not yet pointed to any separation of phthisis into distinct types attacking life at different ages; the phenomena relevant to a question of this kind have perhaps been assigned, so far as they have been observed, rather to changing characters of the human host than to distinctions in type of the invading parasites. To the bacteriologist there is of course nothing novel in the conception of types among the tubercle bacilli causing phthisis; this, if established, would be almost commonplace in view of the earlier detection of types among the enteric group of bacilli, or again in tetanus bacilli or among the cocci of pneumonia and those of cerebro-spinal fever. What is novel is that the detection of distinct types should come sooner from statistical than from bacteriological analysis—for the bacteriologist, although the differences between the "bovine" and "human" types of tubercle bacilli are now well established, has not yet discovered type differences among the "human" tubercle bacilli of phthisis. If bacteriological confirmation of Dr. Brownlee's hypothesis is later forthcoming it is possible, as he points out, that practical results may be gathered in medical treatment of the same kind as those well-known already, for instance, in prophylaxis by specific inoculation against typhoid and paratyphoid infections, or in therapeutics by the use of 'type' sera as in cerebro-spinal fever.

These are obvious speculations which, however alluring, are now useful only if they stimulate further enquiry. But to present value Dr. Brownlee's analyses have already fully demonstrated gain. Whatever be their final explanation in terms of the biology whether of the bacillus or of the host, the statistical descriptions he gives of the resultant distributions of phthisis mortality in age periods and in geographical areas are needed and useful at once in the epidemiological study

of the disease and largely in those directly related to exposure to occupation. Phthisis among miners in Cornwall, for instance, or among boot-makers in Leicestershire cannot be accurately studied except with reference to the characters of the phthisis distribution in those counties. The relative immunity to fatal phthisis among carmen and the sickness or bronchitis-phthisis must not be attributed, as they have been, to the effects of these occupations as such, since the latter is known to be characteristic of Cornwall and the former to be characteristic of Leicestershire respectively. Similar considerations must also be kept in mind in any attempted analysis of the relations between climate and pulmonary disease.

In yet another direction of enquiry the results given in the Report must be taken into account. No estimate of the effects of changing hygienic conditions upon phthisis mortality can be trustworthy if it does ignore what for the present we must be content to call the "inherent" changes in the mortality of the disease during past decades and generations. These changes, happily for the most recent generations, are in the direction of decline. They must be regarded as inherent, as due, that is to say, to the intrinsic biological properties of the disease, for it is plain not only that they occur not without evidence to attribute them to natural hygienic improvement, but that in large part they certainly cannot upon the evidence be so accounted for. The decline is most naturally to be regarded as the ebb of a long epidemic wave to be succeeded perhaps, after a period of latency, by the rise of the next wave in its turn. Unless whether or not and the way of recrudescence—and its explanation can only be given by further study.

References are made in the following pages to an Appendix in which Dr. Brownlie had hoped to set out the detailed protocols of his statistical reductions, for the more complete illustration of his methods. Owing to the difficulties of the present time the printing of this Appendix has been postponed. The Committee hope to add it to a further instalment of the present Report in which Dr. Brownlie proposes at an early date to discuss the various hypotheses which have been framed to account for the decline in the mortality from phthisis during recent years, and to deal further with the geographical and climatic factors in the distribution of the disease.

MEDICAL RESEARCH COMMITTEE.

15, Buckingham Street, Strand, W.C. 2.

4th June 1918.

CONTENTS.

PART I

THE DISCUSSION AND INTERPRETATION OF THE DATA SINCE THE INTRODUCTION OF REGISTRATION.

	PAGE
I.—Introduction	7
II.—General Remarks	8
III.—Phthisis in England, 1850–1910	9
IV.—Phthisis in Scotland, 1860—1910	12
V.—Phthisis in Ireland, 1851–1910	13
VI.—Interpretation of the Forms of the Phthisis Mortality Curves	14
VII.—Occupational Mortality Statistics in reference to the Epidemiology of Phthisis	15
VIII.—Description of the Method of Analysis	17
IX.—Phthisis in Cornwall	27
X.—Phthisis among Females	28
XI.—Relationships between the Different Types present in the Different Counties and Districts	31
XII.—The Relationship of Phthisis to Environment	42
XIII.—On the Interpretation to be placed on the Values of the Correlation Coefficients found in the preceding sections	47

PART II

THE DISCUSSION OF THE DATA PRIOR TO REGISTRATION.

I.—Bills of Mortality in London	8
II.—Phthisis in London in 1801	42
III.—The course of Phthisis in London from 1670 to the present day	43
CONCLUSIONS AND PARTS I. & II.	44
SUMMARY	46

An Investigation into the Epidemiology of Phthisis in Great Britain and Ireland

BY

JOHN BROWNLEE, M.D., D.SC.

Director of the Statistical Department, Medical Research Committee.

I. INTRODUCTION.

The following pages contain an analysis of the statistical information relating to the occurrence of *Phthisis pulmonalis* in England, Scotland and Ireland. The discussion is limited to the cases of this disease which occur above ten years of age, because at this period and later in life *Phthisis pulmonalis* as a cause of death is easy to diagnose, while in addition, the age of the sufferer serves to make it probable that there has been some medical supervision. The accuracy of the information is thus ensured as far as is possible. It is hoped to make a similar study of the death-rates from other tuberculous diseases at a later date.

The data at our disposal relate to the number of deaths alone as at the present moment notification of *Phthisis* has not been sufficiently long in existence to permit of the accumulation of any important body of evidence. The statistics examined are contained in the publications of the Registrars-General of England, Scotland and Ireland. They cover a period of more than fifty years. In spite of some defects they can be matched by the statistics of no other State and even at the present time no other State publishes its data in the same detail as was done in this country in the early years of registration. As far as figures can be expected to furnish information there is, therefore, no lack of equipment. The investigation has not been limited to the statistics of each of the different kingdoms in the British Isles as a whole, but the enquiry has extended as far as information is available to each county in detail and in some instances to groups of registration districts in those counties.

At the beginning of the investigation some doubts arose as to the accuracy of the diagnosis given in the certificates of death in certain districts. As the analysis of the figures proceeded, however, it became evident that the differences found to exist in the age distributions of deaths from phthisis in different districts differences which suggested that the statistics were inaccurate could be explained, as will be seen, on another hypothesis.

It is the intention to treat the subject in four parts:

(1) The discussion of the data which have accumulated since the introduction of the registration of deaths in the year 1856.

(2) The discussion of the data which were recorded before that year.

(3) The discussion of the various hypotheses which have been advanced to explain the decline in the mortality of *Phthisis pulmonalis* during recent years.

(4) The discussion of the geographical and climatological distribution of *Phthisis* in the British Isles.

The first two parts have now been completed and are here published; the third and fourth parts will be issued at a later date.

II. General Remarks.

A few notes regarding the principles on which the statistical investigation of the following pages has been carried out are necessary. As far as possible the figures have been treated independently of any bias due to previous work. This is necessary as many relationships assumed to be proved while seemingly true in reference to some particular trade or in some particular situation have never been subjected to the test of a general investigation. It is for this reason that a careful examination into the manner in which the disease attacks persons at different ages in different parts of the country is specially required. It is not sufficient to compare the number of deaths from Phthisis with the number of persons living in each different district, for the deaths in one district may be almost wholly among young persons while in another the chief ravages of the disease may occur at later ages in life. The comparison is thus quite meaningless. It might be thought that the mean age at which the deaths occur would afford better information, but this is not the case. One reason for this is that populations vary in age constitution: thus in cities there is a large proportion of young persons attracted thither from the country by the prospect of employment. The best criterion is the ratio between the number of deaths at each age period and the number of persons living at the same age-period: a ratio usually defined as the death-rate and expressed in parts per thousand or per million.

Although death rates give at each age period a much better measure of the susceptibility to a disease than deaths, even the former fail to give an exact measure. There is, in fact, only one case in which the death rates at each age period give an exact measure of age mortality, and that is when the population prior to the period in question has not been exposed to the special agent of infection for many years. An instance of this, recent enough to be worthy of note, is to be found in the return of influenza to this country in the year 1889 after an absence of nearly thirty years. In such a case the proportion of persons susceptible to the disease in any age group is undisturbed by previous mortality due to the disease. There is, therefore, no question of the elimination of the susceptible at an earlier age, since earlier death has been due to causes other than the disease in question, causes which have probably, or, it may even be said in the present state of knowledge, certainly, affected persons susceptible or insusceptible in an equal degree. In the case of phthisis, however, the population has been living in an atmosphere of infection from birth, and as part of the mortality at early age has been due to this disease it follows that (to some extent at least) persons naturally susceptible to phthisis have been eliminated by death to a greater degree than persons who by nature are comparatively immune. The result is that the proportion of susceptible persons reaching any age group at any time is reduced, so that the death-rate at any age must be regarded as a measure in defect of the true value.

Further in studying problems of age distribution of disease certain points must be borne in mind. Nearly every disease has a characteristic distribution: the fatality rate or attack rate generally tends to increase as age increases up to a certain point and then to decrease. Thus in examining a diagram showing the distribution of age susceptibility to a disease, there are two points which it is important to note—the one is the age of greatest susceptibility, the other is the manner in which the age susceptibility varies in relation to this age.

If the curve rises rapidly to the age of maximum and thereafter quickly falls away in the cases lie in a very narrow region, while in the case where the curve rises slowly to a maximum and thereafter falls gradually, the mortality is distributed over a large range of all the ages of life. Between these two extreme types any variety of intermediate form may exist. A

diagram (Diagram I) has been constructed to illustrate such types. The first example is that of scarlet fever, a disease in which practically all cases occur in the neighbourhood of five years of age; the second, that of phthisis in London during the decade 1881–1890, shows an approach to and departure from the maximum, so gradual that at all ages of life an appreciable susceptibility to the disease is found; the third example is that of diabetes, where the most frequent age at death lies in the later years of life.

In future pages the age at which the death-rate is greatest will be referred to as the period of maximum fatal susceptibility, or more simply as the period of maximum susceptibility. This is obviously higher than the age at which the maximum number of deaths takes place.

The subject of such age distributions of disease is very important, and a special investigation on the subject will shortly be published. The general result of this investigation is that in all diseases which are definite clinical entities the curves of age distribution follow definite laws. This result is assumed in the succeeding investigation.

III.—Phthisis in England, 1850–1910.

The available data are chiefly contained in the Decennial Supplements of the Registrar-General which have been published for the five decades from that of 1851–1860 up to that of 1891–1900. The death-rates are given in these reports for phthisis for both sexes, for each quinquennial age group from birth up to the age of 25 years, and for each decennial age group thereafter from 25 years up to 75 years. In the earlier decades the age group 75 to 85 years was distinguished, followed by that from 85 years and upwards, but in the later decades the ages from 75 years and upwards are comprised in a single group. This last grouping has therefore been maintained throughout the discussion.

The figures themselves are reproduced in the appendix, but as graphic representations are more easily followed diagrams have been constructed in which the age distribution of the phthisis death-rates is shown for the six decades including and subsequent to that of 1851–1860.

The changes which have taken place in the curves of the death-rates from phthisis from decade to decade during the last century, as exhibited in these diagrams (Diagrams II and III), cannot but be considered remarkable. A glance at the diagram reveals the fact that a great diminution in the mortality from phthisis has taken place since the commencement of registration. This must in itself be regarded as remarkable, but the unequal manner in which the reduction of the mortality is distributed over the various ages is yet more remarkable. The principal phenomenon is the conspicuous fall in the death-rate which has taken place between the ages 20 and 25 years. The fall is not confined to these years, all the later age periods participate, but in a much smaller degree. This reduction must be received as an undoubted fact and cannot be accounted for on the ground of better diagnosis, as phthisis in the young adult is one of the easiest diseases to diagnose, especially if the progress to a fatal termination is rapid.

In addition to this reduction of the mortality at the age period of 20 to 25 years, there is another point about the figures relating to this period of life shown in the diagram referring to males (Diagram II) which demands an explanation, and that is the existence in the first two decades of a discontinuity in the curve of mortality. In no other disease affecting young adult and middle life is a similar phenomenon observed. Acute turning points in a curve describing the course of mortality in a disease are very rare, and have always some special reason. Even in the last decade there are still indications of some special influence at work at the ages 20 to 25 years, but the course of the curve on the whole is smooth, and has no sudden turning point such as is seen between the years of 1851 and 1870.

It will be noted that the curves of the phthisis death-rates for males and for females are absolutely distinctive. The curves representing the mortalities of females (Diagram III) are throughout smooth and continuous as is the case for the later decades with the curve representing the mortality of males. This however does not imply that the influences which determine the female mortalities differ from those which determine the male. That this is so is patent from the fact that the curves representing the mortalities among females for the first two decades exhibit a more rapid increase in the rate of the annual rates as compared at the age period 20 to 25 years and at the immediately succeeding part of their course a more notable flattening than those exhibited by the males for the earlier periods. The interpretation of these points is reserved for a later section.

The curves just described, referring as they do to the whole of the country, are well known, but just because they have been so universally accepted it has happened that the differences shown by the phthisis mortality curves when calculated for limited areas seem to have completely escaped investigation. It is therefore desirable to examine these individually. As the changes observed in the form of the mortality curves have been much more definite among males than among females, the former will be examined in the first place.

Fortunately, owing to the presence of Dr. Farr, full data exist for the earlier years of registration. In these years the deaths due to the diseases specially classified are recorded for males and females separately in each registration district. His successors, however, did not realise the importance of this detail. It has consequently been impossible to follow out many of the lines of enquiry which Dr. Farr's figures suggest. For the decade 1871-80 (except for the country as a whole) no information is available regarding the sex-distribution of phthisis with regard to age. Although Dr. Tatham reintroduced the double classification, he did so only for counties as unit areas and not registration districts. It is to be hoped that in the decennial supplement which Dr. Stevenson is preparing a return will be made to the original practice.

The first stage in the investigation of the data was to calculate the death-rates among males for each age period for every county in England together with the districts of North Wales, South Wales and Monmouthshire for the decades 1881-90 and 1891-1900. The age distributions thus found, which are not reproduced, could be roughly analysed at a glance into two types, one in which the mortality at the early ages was small in comparison with the mortality at the middle ages, of which the chief examples were Lancashire, the West Riding of Yorkshire, Staffordshire, Warwickshire, London and the Home Counties, and the other in which the susceptibility in the early ages was either in excess of that in the middle ages or at least comparable with it, a type distributed more or less generally through the remainder of England and Wales.

In the first of these two types the form of the curve of mortality was such that the ordinates either gradually increase to a maximum lying between the ages of 45 and 55, or, in cases where the susceptibility at early ages was somewhat more marked, rose rapidly at first and then more slowly to the maximum. On the other hand, in the second type, the curve made a very rapid ascent which either leads to a maximum somewhere between the ages of 20 and 25, or, when the susceptibility at early ages is somewhat less marked, to a maximum between the ages of 25 and 35 years. Although the characteristics just described served to classify the two types, another feature is often exhibited by both. This was an increase of mortality at ages subsequent to 55. It will be understood that certain exceptions occurred even to the broad types distinguished above.

As it would take much space to consider the whole of England and Wales a number of districts have been chosen for special investigation with a view to illustrating the previous statements, and also of demonstrating the extremely local manner in which the mortality from phthisis has varied in

different districts during the second half of the nineteenth century. The districts chosen are North Wales, South Wales, Devon, Staffordshire, Lancashire, Norfolk, London and Northumberland. The county of Cornwall should also have had a place here, but as that county presents some interesting peculiarities a special section has been devoted to the consideration of the phenomena. Diagrams (Nos. IV–XI) are given for each of these districts, showing the curves of mortality for each of the four decades 1851–60, 1861–70, 1881–90 and 1891–1900. In the case of London, for which the death-rates for 1842–6 and 1871–80 are available, the extra data have also been exhibited.

From these diagrams it is at once seen how combined mortality curves for England and Wales fail to give any adequate information concerning the epidemiology of phthisis. Nothing could well be more different than the phenomena observed in North Wales and London respectively, yet the existence of these differences could not be suspected from a composite curve applying to England and Wales as a whole.

The contrast between North Wales and London is described in the first place. In North Wales (Diagram IV), in the first decade, the mortality curve makes a very rapid ascent from the first age period shown, reaching a maximum between the ages of 20 and 25 years. The mortality at this age period was extreme, and nearly twice that found for England and Wales as a whole. The decline from this maximum is nearly as rapid. Between the ages of 40 and 60 years the curve is almost horizontal. A second maximum observed between the ages of 65 and 75 years is probably to be explained as an accident due to small numbers. From this maximum the ordinates rapidly approach zero. In the decade 1861–70 the initial rise to the maximum was again remarkably rapid. The mortality was both absolutely greater than in the previous decade, and was fully twice that for the whole country. The mortality curve for the middle ages is again almost horizontal. A final and rapid descent starts about the age of 60 years. The figures for the decade 1871–80 are unfortunately wanting, but with the decade 1881–90 a very different state of affairs is to be observed. The first maximum, which occurs between the ages of 25 and 35, is much less conspicuous than in the previous decades. A fall in the mortality proceeds from this maximum till a minimum is reached in the middle age period, after which there is a slight rise to a second maximum between the ages of 55 and 65. In 1891–1900 the phenomena are essentially similar to those in the decade 1881–90, but the mortality is less at all ages.

In London (Diagram X) the form of the mortality curve is for all decades wholly different. In the first decade, except for some slight excess of mortality at the ages of 20 to 25, the curve is almost symmetrical, rising to a maximum between the ages of 45 and 55 years. With the progress into the later years of the century the chief phenomenon has been the gradual disappearance of the asymmetry. The type of curve found in the decade 1881–90 shows a continuous rise to the age of maximum mortality, and thereafter an almost symmetrical decline. In the last two decades 1891–1900 and 1901–10 there is again, however, a slightly greater susceptibility between the ages of 20 to 25 years than is allowed by symmetry.

The susceptibility curves for South Wales (Diagram V) are very similar to those for North Wales with the important difference that a maximum at middle age is followed in every decade by a second well-marked maximum at old age. The curves for both Norfolk (Diagram IX) and Devon (Diagram VI) also show the same characteristics as those for North Wales, but the mortality at all ages with some minor differences is at a lower level.

The changes in the form of the curves for Staffordshire (Diagram VII) and Lancashire (Diagram VIII) during the period under review show a marked resemblance. In the last two decades they bear a striking similarity to the London curves, but in the decades 1851–60, 1861–70, a great mortality

[illegible] these counties among persons between the ages of 20 to 25 years and among those between the ages of 65 and 75 years. It is in these special age periods that the great decrease in the mortality from phthisis has taken place.

The changes in the form of the curve for Northumberland (Diagram XII) [illegible]. This diagram has been added as an illustration of the different manner in which the mortality from phthisis may vary. The [illegible] characteristic of the Northern counties.

As regards the changes from period to period in the amount of phthisis present at the various ages, it is impossible for anyone to examine this series of diagrams without forming the opinion that, though a fall has taken place during the recent years in the amount of the phthisis mortality at all ages, it is much more marked in the young adult period of life. The general form of the progress of the curves suggests that the amount of phthisis at early ages possibly reached a maximum between the years 1850 and 1870. The indications of this are specially marked in the case of South Wales and Norfolk. In general the heights of the estimates at the age period 20 to 25 years are nearly identical for the decades 1851-60 and 1861-70. Since 1870 the decline has been specially rapid. The decrease in the number of phthisis at the middle ages has on the other hand been extraordinary, but the total fall in the forty years at these ages does not nearly match the fall which took place at the earlier ages between 1870 and 1890.

IV.—Phthisis in Scotland, 1860-1910

The age distribution of the mortality from phthisis in Scotland cannot be followed historically with the same detail as in England. The 1861 data which exist are as follows. The number of deaths from phthisis since the introduction of registration in 1855 have been published for the whole country for each age period in the Annual Reports of the Registrar General of Scotland. In addition the decennial supplements referring specially to the decades 1881-90 and 1891-1900 give the same information for each county.

Full information exists for the cities of Scotland, but unfortunately this apparent advantage recalls with a sense of weariness the trite simile of "the whited sepulchre," in this case, however, better termed "the whited cesspit." At Glasgow and Edinburgh the chief poorhouse hospitals were outside the city boundaries during most of the period, and a large proportion of the deaths from phthisis properly belonging to the city was credited without any remorse of conscience on the part of the city authorities to the comparatively innocent county in which the city happened to be situated. In regard to Edinburgh this fact has with some like accidental concomitants contributed to the general adoption of the system of phthisis dispensaries, the extraordinary low death-rates of that city from this disease demonstrating in the clearest manner the extreme value of such institutions. Prior to 1909 no statistics of any value with regard to phthisis exist for Glasgow and Edinburgh. Aberdeen, having buried its own dead, is on a different footing.

As with England a series of diagrams has been constructed. A comparison of these diagrams (Nos. XII and XIII) with the corresponding diagrams for England (Nos. II and III) shows that though many more deaths from phthisis occur at early ages in Scotland than in England the phenomena observed are fundamentally the same in the two countries. In both countries there has been a steady decline in the amount of the disease since 1860, specially marked at the age period 20 to 25 years.

In the case of Scotland, however, the maximum mortality is still found at the early ages, though the amount of phthisis at these ages has diminished in a surprising manner.

Detailed information for the separate counties, as has been already remarked, is only available for the decades 1881-90 and 1891-1900. These data suffer from the disadvantage that in Scotland many counties are sparsely populated, and consequently the mortality curves show irregularities in form due not to real differences but to the small numbers of deaths from which the death-rates have been calculated. This difficulty can be obviated to some extent by combining the figures for the two decades, and for groups of counties if a certain amount of geographical caution is exercised in the process. Twelve groups of counties have been formed by combining neighbouring counties which possess similar mortality curves.

In these groups of counties considered severally the same phenomena are observed as in England. Diagrams for four groups of counties referring to both sexes are shown:—(1) Shetland (No. XIV); (2) Caithness, Sutherland, Ross, Cromarty, Inverness and Argyll (No. XV); (3) Midlothian (including Edinburgh) (No. XVI); and (4) Lanarkshire and Renfrewshire (including Glasgow) (No. XVII).

The differences between place and place are again best seen in the statistics relating to males.

In the first two groups the mortality occurs chiefly in "young adult" life; in fact, the mortality curve for Shetland may be taken as representing the age distribution of phthisis which is most nearly unaffected by the presence of deaths from phthisis either in "middle age" or in "old age". The curves for the two last groups recall at once the age distribution of mortality found in Lancashire and Staffordshire.

Further observations with reference to these diagrams will be given later.

V. Phthisis in Ireland, 1851-1910.

Much less information is available regarding phthisis in Ireland than for either England or Scotland. The earliest statistics refer to the years in the middle of the last century, and are contained in the volumes of the census. The figures as will presently be seen are far from accurate. After the introduction of registration of deaths in 1864 the statistics much improved in quality, but even then the information given applies only to Ireland as a whole. As in the previous sections relating to England and Scotland, diagrams (XVIII and XIX) illustrating the mortality curves among males and females have been constructed on the same scale and on the same method. The curves for Ireland resemble the type previously found in the western and in the northern districts of Scotland. They show that in Ireland from 1880-1910 the greatest mortality from phthisis occurred between the ages of 20 and 25 years. This mortality between the ages of 20 and 25 years in the districts in which it specially occurs in England was apparently at its maximum between the years of 1850 and 1870. In Ireland, however, the maximum may be placed between the years of 1880 and 1900. This conclusion is based on the interpretation placed upon the early statistics. In the fifties and sixties (Table I) many fewer deaths were recorded between the ages of 20 and 25 years than at the end of the century. The maximum amount was present during the decades 1881-1890 and 1891-1900. In the last decade 1901-1910, a definite fall is observed.

With regard to the higher age periods the amount of phthisis during the last three decades has not greatly changed. What it was in the earliest periods just referred to must be a matter of surmise. The obvious interpretation of the statistics shown in the table is that at high ages a considerable amount of bronchitis was classed as phthisis. The statistics thus afford no certain information. The error, however, is an error in excess, and as bronchitis as a cause of death is infrequent in young adults, it is probable that the number of deaths from phthisis recorded as occurring at the earlier ages is approximately correct.

TABLE I

Death-rates per Million Persons from Phthisis in Ireland for males living at each age period, 1850–1910

Age-period	15–20	20–25	25–35	35–45	45–55	55–65	65–75	75–85	85–
Males									
1850–60	1 147	2 143	4 221	4 194	2 910	2 500	2 206	1 416	812	1 673
1861–70	794	1 978	3 411	3 201	2 074	1 766	1 460	1 348	1 769	1 990
1871–80										
1881–90	647	2 287	4 054	4 215	2 842	2 212	1 926	1 121	676	578
1891–1900	567	2 225	4 073	4 342	3 168	2 249	1 684	799	251	97
1901–1910	599	2 004	3 879	4 106	2 978	2 571	1 887	992	312	165
Females									
1851–60	1 623	2 753	2 714	2 903	2 497	2 560	2 160	2 949	2 983	3 366
1861–70	1 109	2 491	2 774	2 856	2 709	3 144	3 159	4 956	3 701	2 456
1871–80										
1881–90	1 454	3 448	4 103	4 072	2 779	2 112	1 608	677	189	125
1891–1900	1 458	3 410	3 971	4 054	2 929	2 027	1 495	665	225	91
1901–1910	1 256	3 079	3 571	3 699	2 908	1 891	1 349	611	253	120

Further, the mortality curve for the whole of Ireland in recent years resembles closely the mortality curve for Scotland as a whole during the period 1860–1880. It would thus appear that the epidemic in Ireland may be compared with the epidemic in Scotland in its progress, except that the maximum point in the former country is twenty years later than in the latter.

It is probable that differences exist between the districts of Ireland as considerable as have been shown to exist in England and Scotland, but the data necessary to decide such a question have never been published.

VI.—Interpretation of the Forms of the Phthisis Mortality Curves.

An examination of the features exhibited by the curves representing the death-rates from phthisis at each age period for the different parts of the United Kingdom leads naturally to the question: Why do these differences exist? Many causes may be suggested—environment, occupation, climate, elimination of the susceptible persons by natural selection. The influence of conflict these conditions, as has already been stated, will be discussed in a later note. At the present it may be stated that none affords any adequate explanation of the phenomena observed. Each condition individually may modify in some way the response which the human organism makes to the disease, but the influence is within definite limits. The cause of the differences observed is, I think, to be found elsewhere.

I take it that what has hitherto been called *Phthisis pulmonalis* is not one disease, but a mixture of three allied diseases:

(1) A type of phthisis which chiefly affects the young adult, the commonest age at death being between 20 and 25 years.

(2) A type of phthisis which chiefly affects persons at middle age, the commonest age at death in males being between 45 and 55 years.

(3) A type of phthisis which chiefly attacks persons in old age, the commonest age at death being between the ages of 55 and 65 years.

Whether this key is successful in unlocking the heart of the mystery must be left for each reader to judge for himself after I hope, at least, examining the argument developed in the succeeding pages.

VII. Occupational Mortality Statistics in reference to the Epidemiology of Phthisis.

It is not intended in this section to discuss generally the influence of occupations in producing phthisis, but only that part of the evidence furnished by the statistics which seems to throw light on the problems of the epidemiology of phthisis. With regard to the influence of occupation, a note of warning may perhaps be sounded. The whole field is a very difficult one and the interpretation of the figures, unless the greatest care is exercised in drawing deductions, not less dangerous than the interpretation of the Holy Scriptures. As an example of the difficulty it may be noted that, after the age of 35, the mortalities from phthisis among the persons included in the class of commercial clerks and in the class of carmen, carrier, etc., are practically identical, and also identical with the mortality of males in general. Before this age there is a considerable excess of phthisis among commercial clerks, and a corresponding defect of phthisis among carmen, etc. It is hardly likely that these variations are to any extent occupational. It is much more probable that the occupations have been originally selected for reasons of physical fitness or the reverse. This is confirmed when the phthisis mortalities among commercial travellers are considered. In this case the mortalities from phthisis are practically identical throughout with those of the general population, though on a slightly lower level. As commercial travellers are largely chosen from the clerk class, it would seem to be indicated that the fit are put upon the road and the unfit kept upon the stool.

For the purposes of this discussion three groups of industries are of special importance.

The first group is that in which the employees are specially exposed to the dust of silica.* Unfortunately, the Registrar General does not completely distinguish the sub-groups in this set of industries. Thus, bricklayers and masons of all kinds are combined with masons who work in sandstone. The different kinds of stone with which quarrymen work are not separated, nor are those who grind tools with emery distinguished from those who use silica. The mortality curves from phthisis for cutlers, file-cutters, bricklayers, masons and stonemasons, however, illustrate certain points quite definitely. In the accompanying diagram (Diagram XX) these curves are drawn to the same scale as before, and shown in contrast to the phthisis curve for all males of adult age. It will be noticed that in three out of these four groups, though the excess of phthisis is very marked, yet the age distribution of the death-rate does not change very markedly, phthisis being relatively most common between the ages of 45 and 55 among silica workers and the population in general. The curve for the class containing the slate-miner and quarryman, on the other hand, shows a slightly later maximum.

The second group of employés is of those who work in mines (Diagram XXI).† There are five groups of miners, tin, copper, lead, iron and coal, whose mortalities are specially considered by the Registrar General. In one of these, copper-mining, the number of deaths from phthisis in the three years included in the statistics is only fourteen, too small a number on which to base any deductions. With regard to the curves showing the mortalities among lead, iron and coal miners, it is found that a surprising similarity exists. The amount of phthisis reaches its maximum between the ages of 55 and 65 years, or ten years later than that found among silica workers or males in general. With coal miners, among whom phthisis is a comparatively uncommon disease, it is at this age that the only approach to the level of the mortality among males in general is made.

* The statistical observations of Dr. E. L. Collis are of special value in this connection. Milroy Lectures (1915), published in *Public Health* for the same year.

† In Diagram XXI the actual death-rates of the age-periods 25–35 and 35–45 are read-justed by arithmetic. The numbers are so small that the curves have been drawn through these means.

As in Cornish miners there is about twice the mortality of the coalminer at this age and among lead miners about four times. Above the curves for these three groups of miners the mortality curve from phthisis among tin miners is drawn. It is obviously a curve of quite different shape. In its upper part it corresponds very closely with the curve of the phthisis death rate among workers in china, but the mortality does not fall in the manner observed among such. It might be said, in fact, that this curve illustrates a combination between the susceptibility of miners in general to phthisis at the high ages, and that of china workers to an exaggerated amount of phthisis at the relatively ages at which phthisis attacks males in general. The curve of the tin miners' phthisis itself cannot be compared with any of the curves found among china workers or with curves found for other kinds of miners. If not supposed it is very generic. That the latter explanation is the true one is suggested by the curve derived by the discussion of Phthisis in Cornwall.

Late phthisis though found among miners is not confined to them. There is no doubt that in certain districts of the country where mining is not a feature of occupation the late phthisis is quite abundant. This is specially noted in the county of Shropshire. Late phthisis is well marked in both South Wales and North Wales and though in the former there is now a large population and coalmasters yet this occupation cannot be the cause for late phthisis was equally prevalent between the years of 1850 and 1860 before coal mining had become anything like such an important industry. With regard to North Wales there is an explanation. Dr Collis in his Milroy Lectures already referred to gives a table showing the incidence of phthisis in certain employments. The last employment mentioned is that of slate quarriers as distinct from stone quarriers. Though he has found it impossible to obtain the figures showing the death rates at different ages, the mean age at death among these miners is significantly high, at least seven or eight years higher than that among other quarrymen. It has been noted that the only one of the silica industries in which there was a later period of maximum death rate from phthisis was that of quarrying, and that in this industry the workers both in stone and slate were classed together. The high age at which the maximum death-rate occurs suggests that this may be more probably associated with alumina than with silica. The late form of miners phthisis may thus be the result of a chronic irritation of the lungs due to alumina and not to silica since in mining shale is much more commonly met with than sandstone.

In tin mining there is no shale, but granite contains as much felspar as quartz, and, as the former when disintegrated gives rise geologically to clays and slates, alumina might easily play the same part if indeed it be the factor which determines this special susceptibility to phthisis at an age long past the usual.

But again, the amount of late phthisis in many districts is much greater than can be accounted for by the number of miners alone, and, in addition, it is found in districts where there is no mining. There is therefore more than a suggestion that the alteration of the lung tissues associated with the occupation predisposes to the special type of the disease common in the district rather than that the age at which the disease develops is due to the specific conditions of work.

The same is borne out by the fact that at the early ages the amount of phthisis among coal miners conforms to the type of phthisis in the country. Thus in the West Riding of Yorkshire, where there is very little early phthisis among the general population, there is very little among the miners, whereas in South Wales, where early phthisis is exceedingly common, it is also more prevalent among miners. The same phenomenon is noted among boot and shoe makers. In Northampton and Leicester, the chief seats of the boot and

shoe manufacture,* early phthisis is frequent; consequently there is a considerable amount of early phthisis among the boot and shoe makers. On the other hand, I am informed by Dr. Collis that, in London, where there is little or no early phthisis, the incidence of phthisis among boot and shoe makers is at the later ages. I do not feel inclined, therefore, to account for the form of the phthisis curve among tin-miners and among miners in general purely from the point of view that damage in the lung tissue causes in itself an alteration in the age incidence of death, but that it exaggerates the susceptibility to a particular strain of the phthisis organism.

In a sequel to this discussion the geographical distribution of early and late phthisis in the British Isles will be fully discussed. It will be noted there that the chief seats of early phthisis are seaboard and agricultural counties. So much is this so that in the Islands of Shetland there is no phthisis at all excepting the early variety. Thus, probably, the statement of Hippocrates, that the chief ages of susceptibility to phthisis were the ages between 15 to 35 years, is an accurate scientific observation. Between 1850 and 1870 a very large amount of this form of the disease was found in Wales, and, as Greece resembles Wales in many ways,† it is quite possible that in the time of Hippocrates a wide-spread epidemic of early phthisis was in progress, similar to that which affected Wales in the middle of the last century and which is only now subsiding.

VIII.—Description of the Methods of Analysis.

It has already been suggested that the mortality statistics of phthisis in England and Wales indicate the existence of three types of phthisis, one having its maximum mortality among males between the ages 20 to 25 years, the second having its maximum mortality between the ages of 45 and 55, and the third between the ages of 55 and 65 years. If this be the case it is obvious that by some method of arithmetical analysis it should be possible to determine the relative distribution of these three types in each district in England, and, having determined the amount of each of the three types present in any district, to recombine the figures thus found and reconstruct a correct representation of the data for each age period originally analysed.

For clear discussion some terminology is necessary; each of the types of age distribution of phthisis is therefore termed an elementary type. Such elementary type must exhibit the properties of a mortality curve as described in Section II, namely, it must possess a single maximum at some definite age, and must be so constituted that the curve of ascent to and the curve of decline from this maximum respectively are continuous. Each type must also have an easily understood description. It has therefore been decided to call that type of which the maximum mortality is between the ages of 20 and 25 years the "young adult" type; that of which the maximum mortality is between the ages of 45 and 55 years the "middle

* In this case I am inclined to consider there is some chronic poison at work. All forms of leather workers except tanners have a high phthisis death rate. The odour of new leather is characteristically ethereal, and the effect of the inhalation of small quantities of volatile organic substances in depressing health is well known. Further, more phthisis occurs among those employed in boot and shoe shops than among the classes of shopkeeper in general. In the manufacture of indiarubber such poisons are obviously present. In this case the death-rate curve from phthisis conforms to that of the general population in the position of its maximum, but the amount of phthisis is very much greater.

† "I tell you captain, if you look in the maps of the orld, I warrant you sall find in the comparisons betwixt Macedon and Monmouth that the situations, look you, is both alike. There is a river in Macedon, and there is moreover a river at Monmouth." Henry V.

age "type, and that of which the maximum mortality is between the ages of 55 and 65 years the "old age" type. Having determined the relative mortality which each of these types causes at each age period, it should be possible if this theory be correct to describe the mortalities at all age groups in each district examined, by a formula consisting of *a* times the mortality in the first elementary type, *b* times the mortality in the second elementary type, and *c* times the mortality in the third elementary type at each age period, the constants *a*, *b* and *c* being the same for each district for all age groups, but, though the same for each age group in the same district, varying from district to district according as the "young adult," the "middle age" and the "old age" elementary types of phthisis predominate or not.

Such a method of analysis can at first be only tentative. In the case of males, observation of the mortality distributions suggested that the mortality rates found in Shetland and London might represent approximately the "young adult" and "middle age" elementary types. The relative age-mortalities of these districts which were taken as the basis of the first calculations are given in the following table [Table 2]:—

TABLE 2

Showing the Death-Rates per thousand for Phthisis in Shetland and London for specified periods.

Age.	Shetland 1881–1900	London 1881–1890
10–15	16	29
15–20	297	117
20–25	585	220
25–35	406	383
35–45	260	[illegible]
45–55	153	345
55–65	143	404
65–75	129	271
75–	29	114

The first approximation was limited to these two types. This restriction was introduced to save unnecessary labour as there was no local form of curve available which might be expected to describe the age distribution of the "old age" type of the disease. If for the first approximation those districts are selected for the analysis in which the amount of "old age" phthisis seemed to be small, such a procedure is quite sufficiently accurate.

Taking the county of Wiltshire as an example, and assuming *a* and *b* to be the factors by which the "young adult" in Shetland and "middle age" of London rates must be multiplied to represent the mortality rates in the county, the following equations are found:—

Age group.	
10–15	[illegible]
15–20	[illegible]
20–25	[illegible]
25–35	[illegible]
35–45	[illegible]
45–55	[illegible]
55–65	[illegible]
65–75	[illegible]
75–	[illegible]

It will be observed that the first column of figures multiplied by the factor *a* or 2·2 for Shetland for each age period and those multiplied by the factor *b* the similar rates for London. The figures on the right hand side of the equation are the rates for Wiltshire.

It will further be observed that the equations which apply to the nine age groups, 10-15, 20-25, etc., require to be solved for *a* and *b*. It is obvious that unless the values depend on the first two equations, the equations cannot be satisfied exactly since the number of equations exceeds greatly the number of the unknown quantities which it is required to determine. The best values of *a* and *b*, *i.e.* the values which give the best approximation to the figures on the right hand of the equations, must therefore be calculated. The method by which this is done is known by the name of the "method of least squares"; it is described in Appendix A. The resulting values of *a* and *b* calculated are considered the most probable, and from these the theoretical values of the death-rates at each age period are determined and thereafter compared with the values given in the data. In this example it is found $a = \cdot 23$, $b = \cdot 40$. Many counties were similarly examined, and the theoretical values of the multiples obtained afforded results satisfactory as a first approximation. The figures obtained by this analysis, however, exhibit one constant difference from the actual figures as may be seen by a consideration of the results obtained for Wiltshire, Somersetshire, Dorsetshire and Warwickshire (Table 3), though in these districts a fair correspondence between the actual and the calculated values of the death-rates are found.

TABLE 3.

Showing the correspondence of the Actual and Theoretical Values of the Phthisis Death-Rates in certain Counties with the value of a *and* b *as defined in the text.*

Age	Wiltshire.		Somersetshire		Dorsetshire.		Warwickshire	
	Actual	Theoretical.	Actual	Theoretical.	Actual	Theoretical.	Actual.	Theoretical.
10–15 ..	27	22	23	25	21	22	24	27
15–20 ..	95	105	106	118	107	109	104	120
20–25 ..	204	222	236	254	217	237	225	244
25–35 ..	289	243	299	258	269	235	274	326
35–45 ..	260	270	285	269	238	241	404	408
45–55 ..	260	253	248	244	208	216	407	406
55–65 ..	205	217	182	210	160	187	244	346
65–75 ..	115	137	109	136	149	122	179	209
75– ..	54	52	48	50	75	44	72	84
	$a = \cdot 23$		$a = \cdot 29$		$a = \cdot 28$		$a = \cdot 15$	
	$b = \cdot 40$		$b = \cdot 36$		$b = \cdot 32$		$b = \cdot 71$	

The characteristic difference of the theoretical and the actual figures is an excess of the former at the age-group 20–25, followed by a marked defect at the age group 25–35. This tendency, which also appeared in a modified form in certain of the other examples, was evidently due to the curve constructed from the Shetland figures rising too rapidly to a maximum. Such a defect would be corrected by choosing some other series of death-rates which rose to a maximum in "early adult" life, but approached that maximum more gradually. Such a type, after an examination of the different mortality curves exhibited in the previous diagrams, seemed to be afforded by the Irish death-rates, a comparison of which with the death-rates of Shetland is given in the next table (Table 4).

TABLE 4

Showing the Death-Rates from Diabetes at each Age-period in Scotland and Ireland for certain Sexes.

Age	Scotland, 1881–1900	Ireland 1891–1900
5– 15	16	57
15– 20	24	122
20– 25	85	167
25– 30	108	154
30– 45 ..	200	317
45– 55 ..	153	230
55– 65 ..	113	168
65– 75 ..	129	85
75– ..	29	25

Using the death-rates for Ireland given in this table the theoretical values were re-calculated for the counties which were found insufficiently described by the previous calculations. The following table (Table 5) shows how the change in the expression for the "young adult" elementary type of phthisis tends to correct the defect just noted.

TABLE 5

Showing the Result of the Analysis when the figures for Ireland and London were compared.

Age	Wiltshire		Somersetshire		Dorsetshire		Warwickshire	
	Actual	Theoretical	Actual	Theoretical	Actual	Theoretical	Actual	Theoretical
10–15	27	28	23	32	21	29	24	32
15–20	95	111	106	127	107	113	104	125
20–25	234	208	236	245	217	211	225	237
25–35	289	267	299	289	269	259	374	343
35–45 ..	269	277	285	279	248	273	404	414
45–55 ..	209	254	248	246	208	222	407	405
55–65 ..	205	206	182	197	160	178	344	348
65–75 ..	115	114	109	107	149	97	179	194
75– ..	54	45	48	42	75	37	72	80
	$a = 33$		$a = 43$		$a = 38$		$a = 22$	
	$b = 35$		$b = 27$		$b = 25$		$b = 65$	

As these results proved much more satisfactory, the whole of the counties of England were now fitted to the combinations of "elementary types" as represented by the figures for Ireland and London. The resulting fits, allowing for the fact that no account had yet been taken of the presence of old-age phthisis, were much more satisfactory. In certain districts, however, this method was found to be exceedingly defective. This is seen by comparing the results of graduating the statistics of North Wales and South Wales to the selected Ireland and London types. The figures are given in Table 6.

Table 6.

Showing the comparison of the Data for North Wales and South Wales with the combinations of the type of Phthisis Age Distribution found in Ireland and London.

Age.	South Wales.		North Wales.	
	Actual	Theoretical	Actual.	Theoretical.
10–15	52	33	44	42
15–20	178	131	180	167
20–25	286	245	344	311
25–35	304	329	368	381
35–45	279	362	322	368
45–55	301	343	284	325
55–65	327	281	299	261
65–75	283	159	229	142
75–	117	63	70	55
	χ = 33		χ = 57	
	P = 49		P = 36	

These two graduations show a large defect between the actual and the theoretical values at the age-groups 55–65 years and upwards, indicating the importance of the "old age" elementary type not yet taken into account in the calculations.

As there is no district, however, in which any series of age-period death-rates approaches those which might be expected from the presence of the "old age" elementary type of phthisis, other evidence must therefore be sought. In the consideration of occupational death-rates from phthisis it was observed that a notable feature of the curves representing the age mortality of miners from phthisis was the manner in which the death-rates tended to increase to a maximum between the ages of 55 and 65 years. This offered some promise of attack. The mortality curve of coal-miners from phthisis was selected, as this group is much the largest class of miners. The figures are given in Table 7.

Table 7.

Age Period.	[illegible]
15–20	41
20–25	103
25–35	96
35–45	109
45–55	152
55–65	204
65–75	174
75–	69

No rate [illegible] and upwards. [illegible] and [illegible] [illegible] [illegible]

TABLE 8

Age Period	Actual	Theoretical
[illegible] ..	31	30
[illegible] ..	103	[illegible]
[illegible] ..	[illegible]	43
[illegible]	169	173
45–55 ..	252	284
55–65	204	197
65–75	173	94
75– ..	69	40

Examining these figures there is an obvious excess of the actual over the theoretical figures after the age 55 years. Subtracting this excess from the actual figures at the last age groups and repeating the process by fitting the two "elementary types" to the remainder, a new series of figures was obtained. This process was repeated so long as the figures calculated for the high ages were found to be in excess of those which could be represented by the two elementary types. The accumulated excess would, of course, be obtained at any stage of the process by subtracting the values found by the graduation at that stage from the original death-rates at each age period. The manner in which the excess is graduated is shown in the following table (Table 9). In the first column the excess after the first graduation is given, in the second column that after the ninth graduation, and in the third column that after the final graduation.

TABLE 9

Age.	Excess after First Graduation.	[illegible]	[illegible]
35–45	—	—	30
45–55	—	72	92
55–65	47	125	136
65–75	80	128	131
75–	29	51	62

As a criterion on the figures obtained it must be noted that the mortality of the "old age" elementary type cannot be expected to be limited by the age period 35–45 years.

A series of values of the mortalities at each age period in the "young adult," the "middle age," and the "old age" elementary types, suitable for a first approximation, has now been obtained. These are the death-rates from phthisis given in the following table (Table 10). To these values all the counties in England and of the districts of North and South Wales, during the decade 1881–1890, were graduated.

TABLE 10

Age	[illegible]	[illegible]	[illegible]
15–20	27	117	0
20–25	440	276	0
25–35	1·03	1·01	0
35–45	2·17	2·01	0·0
45–55	3·81	3·41	0·2
55–65	4·68	4·64	1·56
65–75	8·0	7·71	4·31
75–	5·0	11·1	9·2

The fits obtained for the six examples in which the graduations by the use of the figures for the "young adult" and "middle age" types alone were previously attempted are shown in the next table (Table 11)

TABLE 11

Age	Wiltshire		Somersetshire		Dorsetshire		Warwickshire	
	Actual	Theoretical	Actual	Theoretical	Actual	Theoretical	Actual	Theoretical
10–15 ..	27	29	23	32	21	31	24	31
15–20 ..	95	113	106	125	107	121	104	123
20–25 ..	204	212	236	233	217	223	225	234
25–35 ..	289	284	299	290	269	255	374	345
35–45 ..	260	269	285	285	238	228	404	422
45–55 ..	260	254	248	249	208	211	407	409
55–65 ..	205	222	182	193	160	193	344	336
65–75 ..	151	134	109	101	149	125	179	185
75– ..	54	53	48	39	75	48	72	76
	$a = \cdot 37$		$a = \cdot 41$		$a = \cdot 48$		$a = \cdot 20$	
	$b = \cdot 28$		$b = \cdot 30$		$b = 1 \cdot 3$		$b = \cdot 68$	
	$c = \cdot 20$		$c = -\cdot 08$		$c = \cdot 35$		$c = 1 \cdot 11$	

TABLE 12

Age	South Wales		North Wales		Cornwall	
	Actual	Theoretical	Actual.	Theoretical.	Actual.	Theoretical
10–15	52	41	44	48	27	35
15–20	178	160	180	186	133	137
20–25	286	292	344	342	272	252
25–35	304	312	368	371	273	288
35–45	279	270	322	309	262	290
45–55	301	297	284	296	362	340
55–65	327	346	299	302	436	390
65–75 .. .	283	271	229	215	286	313
75– ..	117	106	70	82	78	125
	$a = \cdot 71$		$a = \cdot 82$		$a = \cdot 55$	
	$b = \cdot 00$		$b = \cdot 04$		$b = 1 \cdot 3$	
	$c = 1 \cdot 41$		$c = \cdot 92$		$c = 1 \cdot 55$	

It will be observed that, apart from obtaining fits closer to the death-rates at the higher ages, fits have also been obtained closer to the rates at earlier ages. For instance, in South Wales the result of fitting a combination of the three series instead of the two has been to give close results for every age group. There is no reason for surprise in this. It means that the introduction of the "old age" elementary type permits the more accurate graduation of the death rates at ages below fifty-five years to the "young adult" and "middle age" elementary types. This is due to the fact that the "old age" elementary type gives no effective contribution to the death-rate at the earlier ages.

The first approximation is, however, not yet completed. Certain further adjustments are possible. Although the graduation with the elementary types assumed above had yielded positive values of a and b for all the counties of England in the decade 1881–90, it did not follow that the same success would result from the application of the method to the statistics referring to earlier decades. This success is, in fact, not obtained when the statistics of North and South Wales for the decade 1861–70 are subjected to the same analysis. In the case the value of a, b and c given in the following table (Table 13) are obtained.

TABLE 13

	North Wales	South Wales
a	1 · [illegible]	1 · [illegible]
b	[illegible]	[illegible]
c	1 · [illegible]	[illegible]

The quantities *a*, *b* and *c*, as defined previously, represent the quantities of the three types of phthisis present in each case. This definition requires that the values of these factors should be positive. The fact that *b* appears as a negative quantity in three instances is an indication that, even in the districts selected to be found to be positive, the value is in defect of the true value. It follows that the Irish death-rate figures assumed to represent the "young adult" elementary type fail as a sufficient description of that type. The natural presumption is that a certain amount of phthisis of the "middle age" elementary type exists in Ireland. The correction is simple. All that is required is to subtract from the death-rates which have been taken to represent the "young adult" elementary type a sufficient proportion of the "middle age" elementary type to make the value of *b* given in the above table (Table 13) zero.

The first approximation to the three types assumed to exist has now been completed. The second approximation is accomplished by an inverse process. In this process a large number (19) of the counties for which the fits in the first approximate were fairly satisfactory were selected. The values of *a*, *b* and *c* found in the first approximation representing the amounts of each type present in each county were assumed to be correct, and the death-rates at each period in each elementary type obtained from the new data for each age period by the method of least squares. By this method the mortalities due to the period of the three elementary types were ascertained: the values found differed to some extent from the previous values. The comparison is given in Table 14.

TABLE 14

Age	Young Adult		Middle Age		Old Age	
	Mortality per Million	Mortality per Million	Mortality per Million	Mortality per Million	Mortality per Million	Mortality per Million
15–25	63	66	37	37	0	1
25–35	219	219	111	109	0	12
35–45	143	145	25	294	0	2
45–55	148	142	69	75	0	11
55–65	91	111	111	121	30	60
65–75	131	122	84	100	93	101
75–85	94	86	164	160	139	150
85–95	33	0	271	285	144	180
75	3	3	114	117	42	70

As regards the differences found it is to be remembered that a defect in the data of one group results in the fact that it yields values of the mortalities in each age group which are quite independent of those in the adjoining age groups, so that the age mortalities do not necessarily continuously vary. Each series of age mortalities, however, is in its course continuous, that is the mortality curve must rise continually to a maximum and thereafter decline. If the inverse process gives values of the mortalities inconstant with this criterion, these values must be taken as a measure of the evidence of the method. For this reason in the "old age" elementary type, the change of the almost equal values 169 and 151, which represent the mortalities in the age groups 65 to 70 and 70 to 75, to 150 and 180 respectively has been considered to be in contradiction to the evidence which is accounted most trustworthy. This was the most important change made, but certain other values were also adjusted in accordance with a theory described in a paper written some time ago.*

* *Journal of Hygiene*, Vol. XV, p. 25, 1915.

After all these adjustments had been made it was still found that when the new series of values of the age mortalities was used to analyse the various county and district death-rates, the value of the factor c, which describes the amount of "old age" elementary type present in any district, was in some instances negative; the explanation of this, as seen before, must obviously be found in the fact that the values of the death-rates taken to represent the "middle age" elementary type did not describe that type alone, but that at the higher ages these death-rates were larger than they should be on account of the inclusion of a certain number of deaths really due to the "old age" elementary type. The method of correction was made on exactly the same lines as have already been described. The final adjustment being thus completed, it was necessary to recalculate again the relative amounts of the different elementary types present in each county and measured by the values of a, b, c, using the readjusted death rates at each age period found by the inverse process. The final result of the calculations giving the mortalities at each age period in each of the three types is shown in Table 15.

The method of approximation described might be repeated a number of times, but for the purpose of this paper the degree of approximation obtained has been deemed sufficient. From this description the method may seem very intricate, but it is really quite simple although very laborious.

TABLE 15.

Death-Rates among Males at each age group for each elementary type.

Age.	"Young Adult."	"Middle Age."	"Old Age."
10–15	74	23	13
15–20	239	99	18
20–25	459	211	23
25–35	422	365	36
35–45	232	498	64
45–55	123	492	112
55–65	65	359	179
65–75	34	181	180
75–	18	75	75

Taking the figures in Table 15 as representing approximate age mortalities for each type of phthisis, a new analysis of the death-rates for every county in England was made. In the following table (Table 16) the results for the six districts already discussed earlier in this section are shown. The fitting of the values is obviously much improved.

TABLE 16.

Age	Wiltshire		Somersetshire		Dorsetshire		Warwickshire.	
	Actual.	Theoretical.	Actual	Theoretical.	Actual.	Theoretical.	Actual.	Theoretical.
10–15 ..	27	34	23	34	21	37	24	33
15–20 ..	95	109	106	119	107	117	104	116
20–25 ..	204	213	236	235	217	224	225	235
25–35 ..	289	265	299	288	269	254	374	346
35–45 ..	260	271	285	285	238	231	404	422
45–55 ..	260	256	248	252	208	211	407	413
55–65 ..	205	215	182	187	160	186	344	324
65–75 ..	151	139	109	104	149	132	179	188
75– ..	54	59	48	45	75	55	72	79
	a = 27		a = 32		a = 36		a = 16	
	b = ·37		b = ·41		b = ·24		b = ·74	
	c = 35		c = 30		c = ·36		c = 28	

TABLE 17

Age	North Wales		North Wales	
	Actual	Theoretical	Actual	Theoretical
10–15 . .	52	57	44	60
15–20 .	158	156	180	180
20–25 .	286	287	341	341
25–35 .	304	313	348	376
35–45 .	274	282	322	317
45–55 .	201	201	284	261
55–65 .	137	128	200	187
65–75 .	73	284	229	245
75– .	117	121	70	51
	$a = 48$		$a = 58$	
	$b = 17$		$b = 29$	
	$c = 1{\cdot}51$		$c = 88$	

To the above may be added the results for Essex and Worcestershire, together with their previous graduations.

TABLE 18.

Age	Essex			Worcestershire		
		Theoretical			Theoretical	
	Actual	Ireland, London and Coal-mining Districts	Final Series.	Actual	Ireland, London and Coal-mining Districts	Final Series.
10–15 . .	31	24	30	18	28	26
15–20 . .	100	96	92	83	110	89
20–25 . .	178	179	179	176	204	178
25–35 . .	236	240	242	246	259	242
35–45 . .	287	278	272	286	258	272
45–55 . .	230	271	260	242	209	261
55–65 . .	264	277	268	210	167	207
65–75 . .	193	183	191	120	90	125
75– .	81	75	80	52	34	53
	$a = 24$	$a = 17$		$a = 22$	$a = 18$	
	$b = 56$	$b = 41$		$b = 38$	$b = 43$	
	$c = 45$	$c = 62$		$c = 60$	$c = 22$	

Neither of these latter counties was among the nineteen used in the graduation process to determine the final elementary types, yet with the new values thus determined, in Essex, the fit is perfect, while with regard to Worcestershire, in which the previous values failed to represent the data, the fit is hardly less good.

The object of the analysis, however, was not to secure particularly good fits for any selected counties such as Essex or Worcestershire, but to attempt to discover elementary types the combination of which in suitable proportions would give good fits for the great majority of the counties. This end has been successfully accomplished.

It remained to test whether the three elementary types, whose combination had been shown approximately to reproduce the various county rates, age by age, in the decade 1881–1890, performed a similar function in the earlier decades. For this purpose the elementary types were fitted to the death-rates (corrected as in the important counties and districts) for the decades 1851–60 and 1861–70. In general the results were not so good. The chief difference noted occurs in the theoretical figures as compared with the actual in the age-group 20 to 25 years, followed by an excess in age group 25 to 35 years.

This divergence suggested the use of the figures for Shetland which had been used in the first instance. The death rates from phthisis in the early quinquennia in the two earlier decades were accordingly fitted to a combination of the Shetland figures and the figures for the other two elementary types as nearly as determined.

The results obtained were much more satisfactory, the [illegible] corrected, and other improvements resulting.

The meaning of this would seem to be either that with the same type some change in the age of attack may take place with the lapse of time, or that slightly different strains of the same type exist. The variations found, however, are no more than might be expected from the same organism, as I hope to show elsewhere.

IX.—Phthisis in Cornwall.*

In the previous discussion little has been said about the county of Cornwall. This county furnishes an example of conditions observed in no other county in England. Although the peculiarities observed in Cornwall possibly exist to some extent in the adjacent county of Devon they do not exist to a sufficient extent to seriously affect the phthisis death rates for that county as a whole. The analysis of the phthisis death-rate for the county of Cornwall by the method used in the previous section has been found to fail completely, so that if the hypothesis advanced is justified for England as a whole Cornwall must be considered as a special exception. The general phenomena are shown in the accompanying diagrams (Diagrams XXIII and XXIV). The immense death-rate at high ages among males is, of course, due to tin mining, but that explanation does not by any means account for all the facts. In Diagram XXIII the death-rates in the mining and in the non-mining districts of Cornwall are shown for the decade 1861–70. It can be at once observed that during the years of life up to the age of 30 the two death rates are about equal, and that there is a considerable amount of "young adult" phthisis in Cornwall. After this age, however, the course of the two curves shows distinct differences. In the tin mining districts the death rate between the ages of 55 and 65 is twice that obtaining in the non-mining districts. It is to be noted, however, that in the non-mining districts the general form of the phthisis death-rate curve does not differ from that in the mining districts. For recent years this comparison cannot be repeated, as the deaths from phthisis among the different sexes are not separated except for the county as a whole. In Diagram XXIV, therefore, a different method has been followed. The upper curve illustrates the death-rate for Cornwall as a whole for the decade 1891–1900. The lower curve has been obtained by subtracting the total numbers of all tin-miners from the population of Cornwall and the deaths among all tin-miners from the total number of deaths, and then calculating the phthisis death-rates among the remaining persons. As practically all the tin miners work in Cornwall, little error is thus introduced.

It will be noted again, that the form of the two curves is practically identical, though the amount of phthisis among tin-miners is in great excess. If, then, the age incidence of a disease is any guide to the determination of the organism which causes the disease, it must be considered that the phthisis of Cornwall at high ages is a type of its own. It is obvious that the age incidence observed in Cornwall is not a phenomenon due to tin mining, but independent of tin-mining, as it is found in the general population as clearly as among the tin miners. It furnishes a further example of employment increasing the susceptibility to the particular type of phthisis present in a

* The death rates for Cornwall are given in Table II. and in

locality. In [illegible] place reason to suppose [illegible] by logical principles much the most natural. [illegible] arguments on such subjects are open to grave suspicion. The argument which has been advanced that a miner may take phthisis at a later age of life because his lungs have been damaged by silica than if his lungs had been unhampered seems to me very like special pleading. At any rate, it offers no explanation at all of the fact that those who are not tin miners develop phthisis in Cornwall at exactly the same ages as those who are

X. Phthisis among Females.

In the original investigation of the age distribution of phthisis mortality given in the third section of this paper, it was observed that the curves describing the mortality among males showed more variety than those describing the mortality among females. The original analysis was therefore based wholly upon the statistics regarding males. Until this analysis had been brought to a more or less satisfactory conclusion, no success was attained in making an analysis of statistics regarding females. It was found, however, that with the experience derived from the process detailed in the last section a similar analysis could be applied to the mortalities from phthisis observed to occur among females.

The first attempts were made on the hypothesis that the difference, as before shown, for "young adult" and "middle age" elementary types occurring among females might be represented as among males by the statistics for Ireland and London.

The death rates found in these localities are shown in Table 19.

Table 19.

Age	Ireland, 1881-1890	London, 1881-1890
15-20	341	126
20-25	397	160
25-35	403	260
35-45	293	225
45-55	205	259
55-65	143	185
65-75	93	108
75-	18	54

On this hypothesis it was obvious at once in what manner the type of mortality curve found among females had its origin, for the maximum in the "young adult" type in females is at a later age than among males, while the opposite holds for the "middle age" type. The continuity of the curves of mortality for females for the whole of England was thus explained.

A correction, however, was found necessary when the mortalities in Ireland and London were taken as elementary types among males. It was found necessary to subtract one fifth of each of the values of the rates in London at each age from the corresponding death-rate in Ireland. A similar correction was made in the assumed elementary type for females.

With regard to the "old age" elementary type no occupational figures are available for females, nor did any direct furnish evidence of the existence of any kind of age mortality which might be chosen as representing the "old age" elementary type. The series of death-rates used to represent this type was obtained after a series of unsuccessful trials of different methods from the female death-rates for the decade 1881-90 for England and Wales as a whole.

TABLE 20

Age	England and Wales Female Phthisis Rate 1881-1890
15–20	181
20–25	233
25–35	280
35–45	274
45–55	206
55–65	152
65–75	98
75–	40

No attempt was made to separate the old age element from these rates in the manner adopted in the case of the coal-miners' death-rates, i.e. by successive graduation to the "young adult" and "middle age" types. Another method was employed. This was to fit the first three terms of the mortalities at each age period for England as a whole to the corresponding members of the "young adult" and "middle age" mortalities by the method of least squares. Using the factors a and b determined by these equations we would expect to find that the mortalities found for the later ages would be in defect of the actual rates shown for those ages. This proved to be the case. The excess found is shown in Table 21.

TABLE 21.

Age	Excess
35–45	1
45–55	0
55–65	12
65–75	26
75–	4

These excess rates were slightly adjusted, and the values of the mortalities in each age period for each elementary type obtained.

The death-rates among females in all the counties and districts of England and Wales were now calculated on the assumption that these three sets of mortality rates held throughout England and Wales. The values of the amount of the "old age" elementary type in certain cases proved to be negative. This, as before shewn, is evidence that the assumed "middle age" elementary type contains a certain proportion of deaths due to the latter type. Corresponding corrections were made. With these corrections the resulting fits were all fair. There was no outstanding bad fit as in the case of the males of Cornwall, and none even so unsatisfactory as, for instance, the fits obtained for the death-rates among males even after the last correction in the northern counties of England. The final elementary types representing the mortalities among females are given in Table 22.

TABLE 22

Death-rates among Females for each Elementary Type

Age	Young Adult	Middle Age	Old Age
15–20	137	126	9
20–25	91	160	0
25–35	33	260	0
35–45	18	224	3
45–55	141	25	4
55–65	0	158	18
65–75	29	53	19
75–	7	11	9

The values of these constants are interpreted by giving the values for age as the common unit to illustrate the male-female differences. Dr. Wilson-Donaldson and Sir Sidney Jones the maximum of the "young age" (measles) type is earlier than that given by the theoretical figures, but otherwise the fit is good.

TABLE 23.

Age	South Wales		North Wales		Devon		Northumberland		Cardiganshire	
	Actual	Theoretical	Actual	Theoretical	Actual	Theoretical	Actual	Theoretical	Actual	Theoretical
15–20 ..	190	218	183	181	178	190	134	131		
20–25 ..	289	258	263	241	240	243	178	177		
25–35 ..	283	283	242	249	259	261	230	234		
35–45 ..	233	244	240	256	222	226	230	252		
45–55 ..	177	172	156	154	166	171	198	196		
55–65 ..	122	132	111	110	134	127	168	147		
65–75 ..	101	95	65	69	110	111	101	99		
75– ..	25	32	25	24	49	21	26	47		
	$a = 52$		$a = 43$		$a = 48$		$a = 19$			
	$b = 32$		$b = 33$		$b = 21$		$b = 64$			
	$c = 1 61$		$c = 91$		$c = 2 01$		$c = 1 52$			

TABLE 24.

Age	South Wales		North Wales		Devon		Northumberland		Cardiganshire	
	Actual	Theoretical	Actual	Theoretical	Actual	Theoretical	Actual	Theoretical	Actual	Theoretical
15–20	251	316	257	261	163	156	127	125	211	225
20–25	369	372	321	312	203	193	161	156	286	282
25–35	489	461	357	364	229	243	190	197	276	280
35–45	321	329	229	229	253	249	179	188	210	195
45–55	224	233	246	248	248	249	162	166	175	164
55–65	149	177	202	201	243	234	151	167	145	145
65–75	114	129	150	148	219	218	94	98	131	131
75–	66	40	64	59	85	84	18	23	98	98
	$a = 55$		$a = 91$		$a = 39$		$a = 93$		$a = 91$	
	$b = 48$		$b = 66$		$b = 91$		$b = 41$		$b = 28$	
	$c = 2 08$		$c = 2 84$		$c = 2 06$		$c = 78$		$c = 2 52$	

Certain further remarks fall to be made concerning phthisis among females. It has already been recorded that the age at which the female mortality from the "young adult" type of phthisis is greatest is somewhat later than that in the case of the male, and that the most frequent age of death from the "middle age" type of phthisis is somewhat earlier, but there is no very great difference between the total distribution of the two sexes due to these two types. There is, however, a very great difference between the amount of phthisis at high ages, the females showing that there is three times as much "old age" phthisis among males as among females. If these types of phthisis are, as is suggested, separate varieties of the disease, there ought to be a close correlation between the amounts of each type present in the two sexes in the different counties. The correlations found according to the results given in the previous analyses are as follows:

The correlation between the amounts of "young adult" phthisis in males and females is $r = .794$. Between the amounts of the "middle age" phthisis present in males and females it is $r = .716$, and between the amounts of the "old age" type the correlation is $r = .609$.

Considering that the analysis is only approximate these results are in the range of values which might be expected in comparing male and female phthisis. Very high correlation cannot be expected when it is remembered that the sexes are not engaged, as a rule, in employments which would lead to both being infected equally by the disease. To take an extreme instance, the death-rate from phthisis in Cornwall among males is 30 per cent. greater than that among females, this being due to the fact that tin-mining, a prominent industry in Cornwall, predisposes markedly to phthisis. On the other hand, in many agricultural counties, such as Lincolnshire, the death-rate is slightly in excess among females. The lower value for the correlation between the amounts of "old age" phthisis may be reasonably considered due to the fact that as there is only about a third of the amount of this type of phthisis present among females as among males a larger error has been introduced by the process of analysis, which at the best is no more than approximate.

XI. Relationship between the amounts of the Different Types of Phthisis present in the Different Counties and Districts.

As it has been shown that the age distribution of deaths from phthisis in all districts of England can be adequately described on the theory that there are three different types of this disease, each specially affecting one age period, it becomes important to consider how far any relationship exists between the amounts in which the different types are present in different localities.

The method usually employed of measuring degrees of association between two or more varying quantities is to calculate the coefficients of correlation. This method is not necessarily the best, but in the absence of any knowledge as to whether any fundamental relationship exists between these hypothetical types of the disease it is the only method which can be applied. As there are three types of this disease there are three correlation coefficients, one between the amounts of early phthisis and middle age phthisis, one between the amounts of middle age phthisis and old age phthisis, and the remaining between the amounts of old age phthisis and early phthisis. If any correlation either direct or indirect exists between these three types the figures thus calculated should show at least some indication.

The difficulty does not end with the mere statement of it. The analysis of the age distribution of the phthisis death rates has been made by a series of approximations. The correlation coefficients have therefore been calculated for each successive approximation. The values obtained in the first approximation have already been published. In the first approximation, as already described, the analysis for the forty-two counties of England and Wales was made on the assumption that the different types could be represented by the Irish distribution in the case of the "young adult" type, the London distribution in that of the "middle age" type, and the coalminers' phthisis distribution in the case of the "old age" type. From these results the correlation coefficients calculated were found to be respectively:

"Young adult" and "middle age" types	·771
"Young adult" and "old age" types	·553
"Middle age" and "old age" types	·611

After these results had been published, the Irish figures taken as a first approximation to the age distribution of early phthisis, and the London figures which were taken to represent the age distribution of phthisis of middle age were revised. These alterations naturally led to changes in the

numbers representing the amounts of each type present in any locality. The correlation coefficients calculated on the revised figures were found to be reduced in magnitude, and to assume the following values

Correlation coefficients between	Males
"Young adult" and "middle age" types	.674
"Young adult" and "old age" types	.454
"Middle age" and "old age" types	.406

The final approximation, calculated by the application of the three processes as described, led to a further reduction in the values of the correlation coefficients, the new values being

Correlation coefficients between	Males
Young adult" and "middle age" types	.570
"Young adult" and "old age" types	.244
"Middle age" and "old age" types	.384

The forty-two counties and divisions of England and Wales for which the calculation of the three coefficients was made did not include London, and the coefficients referred solely to the male sex. The complete data referring to both sexes give the final results

Correlation coefficients between	Males	Females
"Young adult" and "middle age" types	.654	.739
"Young adult" and "old age" types	.201	.124
"Middle age" and "old age" types	— .284	— .125

The combined effect of all the changes dealt with above is therefore to leave the coefficient of correlation between the "young adult" and "middle age" types still high and negative. The other two coefficients, however, those of the correlations between the "young adult" and "old age" types and the "middle age" and "old age" types, though preserving the same signs as before, are much reduced in value.

The probable errors of all the above coefficients have not been calculated for the following reasons

In the first place, the county rates which have been analysed to give the quantities correlated are based on such large numbers that the error due to random sampling must be small.

In the second place there are large experimental errors in the original data due to biological heterogeneity, to wrongly diagnosed cases, and to a variety of other causes. Such errors have nothing to do with random sampling and cannot be allowed for.

XII.—The Relationship of Phthisis to Environment.

In this section certain aspects of the relationship of the amount of phthisis at different ages to the character of the environment will be discussed. For this purpose some criterion is required. Two criteria of the healthiness of districts suggest themselves. The first criterion is the death-rate in the district, the "standard" death-rate being used in preference to the crude death-rate where it is available. The second criterion is the death-rate from all other causes than phthisis corresponding to the age group selected for examination. It might be thought at first sight that the second criterion was the better, but this may not be the case. Thus, the majority of persons living at any particular age have already been acted upon by the environment for the duration of their life up to that date. In the case of persons between the ages of 20–25 years this is approximately, in many districts, one half of the average lifetime. The death-rate for all ages may therefore give a better indication of the general state of health of a district at any particular age than that for the age itself.

In the first place the correlation coefficients between the amount of each type of phthisis present in the individual counties of England and Wales, as given by the previous analysis and the "standard" death-rate of the corresponding counties, have been calculated. In these calculations the smaller counties have been given equal weight with the larger. This is of doubtful justification, but there seems no way of avoiding some source of error, as weighting according to population leads to equal difficulties. In the first case the defect is error due to small numbers, and in the second to the want of uniformity in the conditions of life which obtain throughout large areas.

The values of the correlation coefficients calculated in the manner described are shown in the following table

TABLE 25.

Table showing the Values of the Coefficients of Correlation between "Standard" Death-Rate and amount of

	"Young Adult" Type of Phthisis	"Middle Age" Type of Phthisis	"Old Age" Type of Phthisis
Males	$r = -.201$	$r = +.421$	$r = +.136$
Females	$r = +.075$	$r = +.291$	$r = -.146$

On examination of this table it will be observed that the correlation between the "standard" death-rate and the amount of the "young adult" type is small negative in sign and of numerical value ·201 in the male sex; positive and nearly zero in the female sex. The correlation between the "standard" death-rate and the amount of "middle age" type of phthisis is considerably larger, and of the same sign for both sexes. It has undoubtedly some definite signification. With regard to the "old age" type the correlation for both sexes is small and of opposite sign. These results seem to show that in districts of more than average death rate there is more than the average amount of "middle age" phthisis, and *vice versa*, and that the distribution of the other two types is more or less independent of environmental influence.

There is, however, a different method of attacking the problem. As a large number of deaths from each type of phthisis is found to occur at special age groups, the relationship between the amount of phthisis occurring in these representative age groups in any district may be compared with some other standard which may be presumed to measure the healthiness of the environment. Three age groups have been chosen. First, that between the ages of 20–25 years as representing the age at which the greatest amount of "young adult" phthisis occurs; secondly, that between 35–45 years of age; and thirdly, that between 55–65 years; the two latter groups representing the same features for the "middle age" and "old age" types respectively.

The statistics relating to the following districts for the decade 1891–1900 have been selected for this part of the investigation, the selection being made to illustrate as far as possible all the different types of curves shown by the phthisis death-rates:—

(1) The Northern Counties (Northumberland, Durham, Westmorland and Cumberland)
(2) Lancashire.
(3) Norfolk and Suffolk.
(4) Hampshire and Sussex.
(5) Gloucester and Somerset.
(6) North Wales.
(7) South Wales.

The method of investigation has been to compare the amount of phthisis present in each of the different registration districts which go to make up the different counties or groups of counties investigated, with the death-rates in the same districts. The only drawback under the disadvantage that the Registrar-General has not recorded the death-rates from phthisis for the two sexes separately in the registration districts but only for the counties themselves. This is a serious defect, as the age distribution of deaths from phthisis is different in the two sexes. In a certain extent this difficulty has been met by investigating the statistics of three districts, namely, North Wales, South Wales and Lancashire, for the only six years for the decade 1861-1870 the last epoch at which such information has been published. The method of investigation has been to calculate the correlation coefficients between the phthisis death-rates in the selected age periods and the death-rates from all other causes in the same age periods in each district, and also the same phthisis death-rate and the crude death-rates of the district as a whole. As the two criteria of unhealthiness used are subject to criticism the correlation coefficients between the death-rates at each age period from all other causes than phthisis, and the crude death-rates of the districts, have also been calculated. With a few exceptions these correlation coefficients are sufficiently high to justify the use of either criterion. For comparison with these coefficients the analysis of the phthisis death-rate into that due to each of these three types for each age period, and for each county or district as a whole, has been made for males alone, as the approximation in the analysis of the crude death-rate has been carried further. The results of these calculations and the correlation coefficients are shown in the accompanying tables, Table 26 (a), (b) and (c). In general it may be said that these tables show the same relations between the different types of phthisis and the environment already found to exist in the previous part of the section (Table 26), namely, (1) that the correlation between the early type of phthisis and environment is zero or possibly negative, which means that the amount of phthisis varies independently of the death-rate or even in an opposite manner, (2) that the same relations hold with regard to the "old age" type of the disease, and (3) that with the "middle age" type it is found that the correlation is positive, or in other words that the death-rate and the amount of phthisis

TABLE 26

Tables showing the Death Rates from Phthisis pulmonalis *at a series of ages as analysed into the various types in certain districts of England and Wales compared with certain correlation coefficients as described in text.*

EXPLANATION.

Y.Y	= Death-rate from phthisis of early type of disease
M.Y	= " " " middle " "
O.Y	= " " " old " "
r_{yx}	= Correlation between the amount of phthisis and the crude death-rate
r_{yo}	= " " " " " death-rate of other causes than phthisis
r_{ox}	= " " " death-rate of other causes and the crude death-rate

TABLE 26

Age period 20-25 years.

District		Y.Y	M.Y	O.Y	r_{yx}	r_{yo}	r_{ox}
North Wales	1891-1900	194	48	20	066	378	221
	1861-1870	168	27	5	129	648	4.0
South Wales	1891-1900	147	39	21	125	074	116
	1861-1870	181	11	11	361	081	624
Norfolk and Suffolk	1891-1900	140	51	9	169	124	480
Northern Counties	1891-1900	139	71	8	359	349	554
[illegible]							
[illegible]	1891-1900	106	85	5	108	170	384
Sussex and Hants.							
[illegible]	1891-1900	117	115	6	267	185	540
Lancashire	1891-1900	94	145	6	614	161	74
	1861-1870	99	116	10	550	148	567

TABLE 6.

Age period 35–45 years.

District		Y.A.	M.A.	O.A.	$r_{y.c}$	$r_{y.o}$	$r_{o.c}$
North Wales	1891–1900	98	112	55	·371	·423	·813
	1861–1870	287	63	84	−·216	·210	·633
South Wales	1891–1900	74	92	58	−·067	+·041	·707
	1861–1870	243	25	121	·068	−·414	·586
Norfolk and Suffolk	1891–1900	71	120	24	+·666	+·678	·815
Northern Counties	1891–1900	70	168	23	·571	·824	·759
Gloucestershire and Somersetshire	1891–1900	53	193	8	·791	·485	·725
Sussex and Hampshire	1891–1900	59	267	7	·598	·407	·828
Lancashire	1891–1900	12	343	18	·795	·836	·942
	1861–1870	156	260	45	·755	·830	·830

TABLE 6a.

Age period 55–65 years.

District		Y.A.	M.A.	O.A.	$r_{y.c}$	$r_{y.o}$	$r_{o.c}$
North Wales	1891–1900	28	81	154	·350	·057	·823
	1861–1870	80	45	234	·245	·022	·776
South Wales	1891–1900	21	67	163	−·067	−·206	·905
	1861–1870	68	18	339	−·013	−·239	·777
Norfolk and Suffolk	1891–1900	20	87	68	+·555	+·544	·895
Northern Counties	1891–1900	20	121	65	·481	·481	·876
Gloucestershire and Somersetshire	1891–1900	15	139	23	·639	·431	·794
Sussex and Hampshire	1891–1900	17	193	21	·594	·501	·862
Lancashire	1891–1900	3	248	49	·620	·671	·953
	1861–1870	44	187	127	·431	·458	·916

of this type increase together. In order to illustrate the range of variation of the correlation coefficients more clearly all the values have been collected in the following table (Table 27). The method in which the table has been

TABLE 27.

Ratio of the Death Rate from "middle age" type of Phthisis to that of the sum of the Death Rates due to the "young adult" and "old age" types of the disease	Correlation Coefficients	Means
≥ 10 < 12	·795 ·836	·816
≥ 8 < 10	.. ..	
≥ 6 ≤ 8 ..	.. ..	
> 4 ≤ 6 ..	·614 ·598 ·594 ·620 ·461 ·407 ·501 ·671 ..	·557
> 2 ≤ 4 ..	·791 ·639 ·185 ·431	·587
> ½ ≤ 2 ..	·108 ·267 ·666 ·571 ·755 ·371 −·067 ·555 ·481 ·441 ·170 ·185 ·123 ·041 ·678 ·824 ·830 ·458 ·544 ·481	·439
> ¼ ≤ ½	·169 ·359 ·550 ·350 −·067 ·124 ·459 ·133 ·057 ·206	·168
> ⅛ ≤ ¼ ..	·005 ·125 ·216 ·358 ·074 ·210 ..	·094
> 1/16 ≤ ⅛ ..	·245 ·022	·134
> 1/32 ≤ 1/16 ..	.. ..	
> 1/64 ≤ 1/32 ..	.. ..	—
> 0 ≤ 1/64	.. ..	—
> 1/128 ≤ 0	·068 ·164	·241
> 1/256 ≤ 1/128 ..	.. ..	—
> 1/512 ≤ 1/256 ..	.. ..	
≤ 1/512	·129 ·361 −·013 −·048 −·081 ·249	·146

constituted is as follows. The portions of the phthisis death-rate corresponding to the "old age" and "young adult" types of phthisis have been added together, as in both these cases the correlation with the environment is zero or possibly negative; the portion of the death-rate due to the "middle age" type being kept separate. The ratio of these two portions has been taken for each group of counties and for all age periods for which calculations have been made. The districts are classified according to the ratio which the sum of the amount of "young adult" and "old age" types of phthisis bears to the amount of the "middle age" type.

The two sets of correlation coefficients, namely, those deduced from the death-rate from all other causes at the specified age and those from the crude death-rate of the district as a whole, have been treated as of equal value. Each correlation coefficient is placed opposite to the appropriate ratio and a mean taken of the whole observations in each compartment. It will be noticed that the progress in value of the ratio corresponds essentially with the progress in value of the correlation coefficient. When the death-rate from "middle age" phthisis is about four or five times that of the other two types combined, the correlation between the death-rates of a district and the amount of phthisis is .557; when the amounts are about equal the correlations are .429; and when the amount of "middle age" phthisis is less than one-fourth of that of the other two combined the correlation is slightly negative. This affords some confirmation of the result obtained in the previous section. It will be noticed that the experimental error of the correlation coefficient must be very great, and that it is only due to the fact that a considerable number of coefficients have been calculated that it is possible to detect any approach to regularity.

In the previous remarks no difference has been made in the two sets of observations, namely, those for the decade 1891–1900 for the combined sexes and those for the decade 1861–1870 for the male sex alone. I think it may be fairly said that the two sets of observations show a surprising resemblance and that the differences between them are only such as would be expected, on the present theory, by the alteration in the proportionate amounts of the different types of phthisis between the two dates, when it is remembered that the phthisis of "middle age" is correlated positively with the death-rate and that of the "young adult" and "old age" types negatively, but that only to a slight degree.

A few words are now necessary concerning the interpretation of the results arrived at. It would seem that phthisis of the "middle age" type is an infection of which the virulence is increased by the presence of unhealthy conditions, and that the phthisis of youth and "old age" are infections of which the spread is not affected by such conditions. It might seem a priori extraordinary that an infectious disease should not be more abundant where there is more overcrowding, but this is a well-known phenomenon of one common infectious disease, namely, scarlet fever. In some towns it is quite true, it is more common in the lower than in the upper class districts, but this is by no means the rule. Especially when the attack-rates are calculated against the numbers of children living under ten years of age, the ages at which scarlet fever is acquired, very surprising divergences from what might be expected become manifest. As this matter is specially important, and as published figures are scarce, I annex the following table illustrating the differences found in Glasgow in the five years surrounding 1898–1902. The table is modified from one given in an old report. In the first column the reference number of the old Glasgow sanitary district is given; in the fourth column the average number of persons living per room; and in the sixth column the attack-rate by scarlet fever per 10,000 children living under 10 years of age. It will be noticed that as room-density increases the amount of scarlet fever decreases, and that in the best parts of the city there is nearly

three times as much scarlet fever as in the worst. No matter how much stress may be laid on the lack of notification in the lower parts of the city as explaining the discrepancy, such a difference cannot be explained away. There is therefore nothing ridiculous in the idea of assuming that one variety of phthisis is more or less independent of environmental conditions while another variety exhibits an opposite phenomenon.

TABLE 28.

Table showing the Attack Rate from Scarlet Fever per 10,000 children living under the age of 10 years, compared with the number of persons per occupied room.

Districts.	Population.	No. of Children under 10 years of age.	No. of Persons per room.	No. of notified Cases of Scarlet Fever, 1898–1902.	Attack Rate per 10,000 Children per annum.
Group I.—26, 27, 28, 29	34,868	4,451	·5 — 1	864	388·2
Group II.—17, 24, 25 B.W. ..	83,255	13,605	1 — 1·5	2,148	315·6
Group III.—1, 9, 12, 15, 19, 23, 30	201,098	43,173	1·5 — 2·0	5,439	251·8
Group IV.—5, 10, 14	87,885	20,834	2·00 — 2·25	2,184	209·6
Group V.—3, 4, 6, 11, 13, 18, 20, 21, 22, 31, Sp. & Rv.	237,161	56,898	2·25 — 2·50	5,610	197·0
Group VI.—2, 7, 8, 16	117,445	30,185	2·50 — 2·75	2,091	138·4

XIII. ON THE INTERPRETATION TO BE PLACED ON THE VALUES OF THE CORRELATION COEFFICIENTS.

In the three last sections account has been taken of a certain number of correlation coefficients which generally agree. It is found that there is between the presence of the three types of phthisis in a district a certain relationship, that between the amount of "young adult" type and of the "middle age" type there is a high negative correlation, a correlation which may be measured roughly probably as −·65. There is a small positive correlation between the amount of the "young adult" type and the "old age" type which may be taken as possibly +·2, among males, and there is a negative correlation between the amount of the "middle age" type and that of the "old age" type which may perhaps be placed at −·3. We thus have an association of a positive nature between phthisis in youth and phthisis in old age. What this means is somewhat doubtful. One explanation which suggests itself is that the phthisis of youth and the phthisis of old age may be the same disease. Many cases are known of persons recognised as suffering from phthisis in early youth who, having recovered from the disease and subsequently carried through a strenuous life's work, in the autumn of their life again developed symptoms which ultimately led to death. In some of these cases it is difficult to believe that the infection lay latent during the long interval, and a re-infection seems a more probable solution; on the other hand, there are many cases of old age phthisis which occur in persons who during their early years showed no evidence which led either themselves, their physicians or their friends to believe that they were suffering from phthisis even in a mild

term. It is, on the whole, probable that the small positive correlations found means that only a small number of people become infected by the tubercle bacillus in youth, hold it at bay during the years of manhood, but succumb to the infection in old age. On this view most of the cases of "old age" tubercle infections must be regarded as new.

The negative correlation between the amount of the "young adult" type of phthisis and the "middle age" type is on a different footing. It is high in value and constant in occurrence. It is impossible here fully to discuss the different theories on which the relationship might be explained, but some of these theories may be briefly stated.

(1) It is possible that when a large number of persons die between the ages of 20-25 years from phthisis the number of survivors in the population at the ages of 30-50 who are susceptible to phthisis may be so few as to limit the possibility of any great number of cases at these ages.

(2) It is, however, equally possible and equally probable that with a widespread infection in youth many people establish an active immunity to phthisis, an immunity which protects them ever against a somewhat different strain of the organism for many subsequent years or even for the whole of life. It is well known that of those persons whose lungs have been affected by tubercle only a small percentage die of the disease. My own impression, from examining applicants for the position of nurses in the hospitals I had charge of—persons coming largely from the northern districts of Scotland, where early phthisis is very prevalent—was that about one in four showed signs of differences between the apices of the two lungs of greater degree than could be accounted for by physiological differences. If this be the case, this theory of the etiology of the correlation coefficient cannot be dismissed without careful consideration.

(3) When the geographical distribution of the two types is considered it is found that in the coast districts there is more early phthisis, and that in the urban districts from London to the northern midlands the "middle age" type is most prevalent. If towns predispose to one type and the rains and winds of the sea coast to another type, there would necessarily be a high negative correlation between the amounts of the two types. In the correlation diagram XXII, which shows the age distribution of phthisis among women and agricultural labourers, workers most exposed to the action of the elements, is of interest. This point will be discussed at a later date.

PART II.

I. The Rates of Mortality of London.

The histories of all infectious diseases which can be ascertained show that there are periods when these diseases are more prevalent and periods when they are less prevalent. This waxing or waning in intensity in many cases has little or nothing to do with any change, sanitary or other. The first of two phenomena accidentally associated has often been ascribed as the cause of an epidemic, but it has been found later that when the same antecedent has recurred the event has been different. It is, therefore, specially important to inquire as to whether there is any parallel example to the recent decline in the amount of phthisis. Data on this point are very scanty, but there is one long series of statistics in existence in which an attempt has been made to distinguish the deaths due to phthisis. This series

relates to London, and is contained in the "Bills of Mortality." It is not intended to give in this place a history of these Bills, but before the evidence they afford can be used the data must be subjected to suitable criticism. The data range from the year 1593 up to 1845. The early returns give the number of christenings and burials, and also the number of deaths due to plague. In the year 1629 the causes of death were first classified. From this date, with the exception of an interval between 1637 and 1646, a continuous series of these Bills is extant.

In these Bills one of the constant causes of death given among about thirty others is "consumption." Classification has altered in many respects, but this entry has remained unaltered. It is thus possible to follow the variation of this disease in London for more than two centuries, once it can be affirmed that the term "consumption" connotes an actual disease.

In the early days of the Bills of Mortality the diagnosis of the disease recorded in the tables is not directly that of a physician. As described by Graunt,* the method of compiling the "Bills" prior to the year 1660 leaves room to doubt the accuracy of the diagnoses. In his own words it is as follows:—

> "When any one dies, then either by tolling, or ringing of a Bell, or by bespeaking of a Grave of the *Sexton*, the same is known to the *Searchers*, corresponding with the said *Sexton*.
>
> "The *Searchers* hereupon (who are antient Matrons, sworn to their Office) repair to the place, where the dead Corps lies, and by view of the same, and by other enquiries, they examine by what *Disease* or *Casualty* the Corps died. Hereupon they make their Report to the *Parish-Clerk*, and he, every *Tuesday*-night, carries an *Accompt* of all the *Burials* and *Christenings*, happening that Week, to the *Clerk* of the *Hall*."

In section 10, page 26, he also makes the further remarks:—

> "To conclude, In many of these cases the *Searchers* are able to report the opinion of the *Physician*, who was with the Patient, as they receive the same from the Friends of the Defunct."

In Section 7, page 24, he also makes the following remarks:

> "As for *Consumptions*, if the *Searchers* do but truly Report (as they may) whether the dead Corps were very lean, and worn away, it matters not to many of our purposes, whether the Disease were exactly the same, as *Physicians* define it in their Books. Moreover, In case a man of seventy five years old died of a Cough (of which had he been free, he might have possibly lived to ninety) I esteem it little errour (as to many of our purposes) if this Person be in the Table of *Casualties*, reckoned among the *Aged*, and not placed under the Title of *Coughs*."

Finally, in discussing coughs, in section 37, page 56, he states:—

> "The *Tyssick* seems to be quite worn away, but that it is probable the same is entred as *Cough* or *Consumption*."

In the synopsis of the Bills referred to by Graunt, the headings that might be associated are:—(1) Cold and cough, (2) Consumption and cough, (3) Tyssick.

The second heading contains the great bulk of the cases. These notes do not suggest that the figures can be relied upon as more than rough indications of the prevalence of consumption, but when it is considered that consumption is a fairly definite disease, that bronchitis is practically as a cause of death confined to aged persons alone, and that the deaths due to it will be commonly included among the deaths due to old age, of which the number given is found on examination to be sufficiently large to cover that cause, it may be taken that the figures are at least not obviously in error.

* Natural and Political Observations mentioned in the following Index and made upon the Bills of Mortality, Eight Impression, p. 19.

With the end of the seventeenth century there was a great improvement in the art of medicine, contributed to largely by the great physicians, Sydenham and Morton. When the descriptions given by these physicians are collated with those contained in the successive works on medicine, published between 1670 and 1840, it is seen that the principles of the diagnosis of phthisis have remained essentially the same during these long periods. If the persons dying of consumption received medical attention it is therefore, safe to conclude that the figures for the successive years can be compared. Further, in an increasing degree the deaths would be among persons who had some medical attendance, and whose diseases probably would be diagnosed in accordance with the signs and symptoms as laid down by the authority of Sydenham and Morton.

Though this may be the case the opinion of contemporary physicians of noted eminence in their profession is not always so favourable. From the time of Graunt, frequent references by such are made to the *Bills of Mortality*. It is therefore necessary to consider each of these criticisms carefully. The chief are quoted verbatim.

Fothergill,* writing in the middle of the eighteenth century, considered the death-rate from phthisis as much too high. His criticisms are as follows:

> "The three most capital articles in our general Bills are Consumption, Convulsions and Fevers, under which last article are commonly ranked not only common inflammatory fevers but every other species that is usually enumerated; yet the number of those who are said to die of fevers seldom equals, very seldom exceeds, the number of those who are said to die of Consumption, nay, it is much the most common for those to be as four to three of fevers. Foreigners who are ignorant in what manner our Bills are compiled, give it out that Consumption is the grand epidemic of England. The searchers are commonly two as poor and ignorant persons as the parish affords; these are to see all the dead bodies, and to report to the Company of Parish Clerks of what disease they died. If the body is emaciated, which may happen even from an acute fever, it is enough for them to place it to the account of Consumption, though the death of the party was perhaps owing to a disease specifically different; and thus a monstrous account is framed by the ignorance of the searchers, to the disgrace of our country, and even so far as to discourage some foreigners from coming among us."

In this connection it may be observed that the number of deaths from consumption amounted to no more than 19 per cent. of the total deaths occurring from all causes at this period.

With these criticisms Heberden,† writing at the beginning of the succeeding century, does not concur, observing that

> "The agreement of the Bills with each other does alone carry with it a strong proof that the numbers under the several articles are by no means set down at random, but must be taken from the uniform operation of some permanent cause. While the gradual changes they exhibit in particular diseases correspond to the alterations which in time, are known to take place in the channels through which the great stream of mortality is constantly flowing."

Willan,‡ writing in 1797, discusses the matter, and in the main agrees with the Bill of Mortality. He gives a list of the causes of death of 245 persons, whom he personally attended, during the years 1795-96. As the matter

* [illegible]

† [illegible]

‡ [illegible]

TABLE 29.

Table extracted from Willan's Report on the Diseases in London (p. 198).

"Out of 4,500 persons admitted under my care, in the years 1795 and 1796 245 died from the following disorders"

Pulmonary Consumption	77	Ulcerated malignant sore Throat	3
Haemorrhagy from the Lungs	5	Peritoneal Inflammation	2
Peripneumony	1	Inflammation of the bowels and Hernia	4
Whooping cough	3	Dysentery	1
Cough succeeding the Measles	6	Ulcer of the Rectum	1
Smallpox	20	Psoas Abscess	1
Scarlatina Anginosa	2	Gangrenous Ulcer	1
Malignant Fever	8	Tetanus, with locked jaw	2
Slow Fever	3	Acute Disease of Infants under 2 years of age	14
Summer Fever	1	Hydrocephalus	7
Puerperal Fever	2	Stoppage of the Bowels	2
Scrophula, Rickets, and Tabes Mesenterica	10	Disorder of the Stomach and bowels from excess in drinking Spirits	14
Scirrhus and Cancer Uteri	3	Apoplexy	6
Cancer of the Breast	3	Paralysis	8
Gradual decline mostly with Scirrhus Liver and Dropsy	21	Obstinate Headache	1
Decay from Old Age	7	Menorrhagia	3
Jaundice	1	Abortion	1
Stone	1		

is of very considerable importance this table is transcribed. The deaths that he attributes to pulmonary consumption are there about one-third of the total deaths, a proportion quite in keeping with that seen in the *Bills of Mortality*. His comments on nomenclature are important and are as follows:

> "In my own list the article of pulmonary consumption includes cases of ulceration of the lungs, and alterations of their texture in consequence of inflammation and repeated catarrhs. I apprehend not more than a fourth part of the whole number of cases put down could be referred to proper Phthisis arising from the slow and successive suppurations of tubercles in strumous constitutions."

In other words, the cases he calls consumption are exactly those which modern pathology would regard as due to that cause.

Later, in 1808, Dr. Woolcombe published the result of his enquiries into medical statistics in a book chiefly occupied with the discussion of the increase of consumption. Many of his figures are taken from the Bills of Mortality, but he gives some additional information which is corroborative to a certain extent. The actual increase he accepts as a fact.

My own view is that those who hold that the number of deaths ascribed to consumption gives a fair measure of the amount of phthisis have formed an accurate opinion, an opinion which some other evidence to be given later confirms.

In the absence of accurate estimates of the population for the area in London to which the Bills of Mortality apply, it is necessary to take the ratios of the number of deaths from phthisis to the total deaths. This method has disadvantages, but within limits it affords the basis of sound conclusions. The ratios calculated are shewn in the accompanying diagram [Diagram XXV]. It will be noticed that the variations in the ratios are extreme. The difference seems much larger than can be accounted for by any of the causes which have been referred to. It would seem that in the middle of the seventeenth century there was some excess of phthisis. The percentage of phthisis deaths to the total deaths was as high as 20 per cent. in the decade 1650–1660. After this the ratio fell to about 12 per cent. in the year 1709. The process is continuous. One observation, not included in the curve, seems to afford an exception, but this refers to the decade 1661–1665, a quinquennium in which

the great mortality from plague disturbs the rates so seriously as to make the observations of a different character from the rest. From the year 1700 the rate steadily increased, rising from 12 per cent. in that year to the maximum of 26 per cent. at the end of the century. With the exception of the new century an equally steady decline began. This progress cannot possibly be wholly meaningless. It must represent something in nature, and the very strong probability is that it represents a long epidemic wave of phthisis which reached a maximum in the early years of the nineteenth century. The possible error is that other diseases have declined in amount, and that phthisis has remained more or less stationary. Now there is no question that the death-rate in London declined during the eighteenth century. That of the whole country seems to have fallen from about 35 per thousand to 26 per thousand between 1730 and 1800; but it seems equally definite that the death-rate from phthisis was also proportionally increasing with respect to the total death-rate. In addition, it is almost proved that the type of phthisis found in London is markedly increased by unhealthy conditions, yet it is found that with a marked improvement in the general death-rate the proportionate mortality from phthisis constantly increased. The argument will be completed in the next section, but even with the information so far described it would seem that the easiest explanation of the facts is that an epidemic wave of phthisis spread steadily over London in the eighteenth century, culminated about 1800, and has since declined.

II. Phthisis in London in 1801.

The only information directly available regarding the mortality from phthisis in London in 1801 is the number of deaths recorded as due to "consumption" in the area for which the deaths are recorded in the Bills of Mortality. These Bills, however, fortunately contain the ages at which the deaths from all causes occurred, and though the data refer to males and females combined they are yet very valuable.

As we have seen, the distribution of phthisis with regard to age in London has been typically that of the middle-aged type, and in the decade 1881-1890 was almost purely so. In the discussion in the first part of this paper it was found necessary to separate the sexes, before the phenomena present in any district could be adequately analysed, and this procedure would certainly have been followed in this section had the statistics available in the earlier part of last century distinguished the deaths by sexes in each age period. This information is, however, not available for the year 1801, but as has been seen hitherto the variety of phthisis which causes death in middle age does not show greatly differing mortality curves in males and females. For purposes of inquiry a curve of the death-rates of the sexes combined has been constructed for the decade 1891-1900. This curve is found to have its maximum about the age of forty-three, and to be nearly bi-laterally symmetrical. The earliest date for which age distribution of the population can be obtained is 1821. At the date the ages of the whole population were not recorded, but a sufficiently large percentage—84 per cent.—of the population made the necessary returns to allow of a very fairly accurate estimation of the ages of the whole population. It is extremely an question of a certain number of persons failing to return their ages throughout the city. To that case the error introduced by human psychology would have been difficult to correct, but the defective returns relate to whole parishes. It is therefore probable that the figures given represent the age-distribution of the whole city with fair accuracy. The total numbers of persons living in 1821

and 1841, in the areas to which the Bills of Mortality refer in the year 1801, are given by Farr.* With these, and with the relative ages, a population has been constructed for the areas of London covered by the Bills of Mortality for the year 1801. As the total population in 1821 is almost exactly a geometrical mean between the total population in 1801 and 1841, this law has been assumed to hold for each age period, and the age distribution calculated for 1801 for both males and females separately. When the males and the females are added together the total calculation is within 1 per cent. of the total actually enumerated at the census. It may therefore be taken as approximately accurate. With this population the death-rate at each age, found from all diseases, has been calculated. This mortality curve is shown in the diagram XXVI. The diagram is based on an average of the deaths for the five years period, 1799 to 1803. It is in rough accord with what might be expected at that time, but as all the deaths are not included in the Bills of Mortality the death-rates at each age must be considered throughout as in slight defect.

Four curves are shown in the diagram. The uppermost is the curve showing the death-rates at each age period from all causes in 1801; beneath this is placed the similar curve for the decade 1891–1900. The differences between the death-rates at each age period, drawn to twice the scale, are shown in the third curve, while the fourth curve, placed immediately beneath the latter and also drawn to twice the scale, shows the form of the curve of the death-rates at each age period from phthisis in London in the last decade.

It will be noticed that the portion of the curves representing death-rates at each age period in London in 1801, at which the greatest proportional excess over the death-rate curve for London in 1891–1900 occurs, corresponds with the ages at which it would naturally be expected if phthisis had been much more prevalent in this earlier epoch. The age distribution of this excess is practically identical with that showing phthisis as it has hitherto been observed to occur in London. This, however, is in itself not sufficient proof that the excess is due to phthisis, since it has been found that it is at this period of middle life that unhealthy conditions make their chief influence felt. Since, however, the death-rate from all causes, a death-rate in defect of the real death-rate from the deficiency in the notification of deaths, is seen to be much higher than that existing between 1890–1900, and since the proportion of deaths from consumption to the total deaths was in this decade only about one-third of that existing in the year 1801, the combined evidence must be taken as sufficient to show that the amount of phthisis in London in the year 1801 was very great.

III. The Course of Phthisis in London from 1670 up to the Present Day.

Having in the previous sections on the Bills of Mortality in London, decided with a strong probability that the figures referring to the deaths from consumption really represent approximately the numbers of deaths from that disease, it becomes possible to trace to a certain extent the manner in which the amount of phthisis has varied in London for over two hundred years. A accurate population [illegible] 1800 it has not been possible to obtain the exact death-rate, but the proportionate mortality [illegible] gives a result which is comparatively trustworthy. It may [illegible] doubt at all that the amount of phthisis in 1800 [illegible] relatively to present-day standards. The curve (Diagram XXV) shows at first something and the [illegible] explanation is that from the beginning of the

* [illegible]

eighteenth century to the beginning of the nineteenth century consumption increased in incidence, and from the latter point steadily diminished. Though the increase in the proportionate mortality does not prove that the disease was increasing in the decrease that it was decreasing the probabilities that there was a large amount of phthisis in London in 1800 are very great.

In the first period for which accurate statistics exist namely that between 1840 and 1850, the amount of phthisis was about half of that I estimate for the earlier epoch, and from this point the decline is summarily well proven. If this view be taken it follows that an epidemic of phthisis in London is coming to an end the course of which apparently has been something like two hundred years.

CONCLUSIONS TO PARTS I AND II

The results of this investigation point, I think, to the conclusion that the disease known as *Phthisis pulmonalis* is not a single disease as is commonly understood, but rather a group of diseases, coming thus into line with typhoid fever and bacillary dysentery both of which are now known to consist of groups of diseases of which the causal organisms possess similar properties and produce fevers which run almost the same course.

If this conclusion is found justified many important consequences must follow. For instance, from analogy with other diseases it would seem that if any kind of vaccine or serum treatment is adopted it will be necessary to see that the vaccine or serum is made with the proper organism. It is useless to try and protect against paratyphoid fever with an anti-typhoid vaccine, and the same statement is true of many other allied diseases. It can thus well be imagined that treatment with tuberculin will have little or no effect in, in the course of phthisis, there are differences between the various strains of the tubercle bacilli comparable to that found between the organisms of typhoid and paratyphoid fever. This possibility may explain the different value placed by physicians on curative properties of tuberculin. It is quite possible that the claims on behalf of tuberculin are fully justified in certain instances. In my own clinical experience, for instance, I have seen one or two cases of extensive lupus in which there seemed to be no doubt that the patient was very greatly benefited by the use of tuberculin; yet in other cases treated at the same time, and in the same manner, no improvement occurred, and even in some cases apparently an exacerbation of the disease seemed to be the result. This view would also accord with my experience in the tuberculin treatment of phthisis, from which I cannot say I ever saw any demonstrable benefit. Glasgow is a city in which, according to analysis previously given,* there is little phthisis of the "middle age" type. It is probable that vaccines are largely made from this type, as it is the prevalent type in London. There would thus be little probability of the treatment being appropriate except in a small number of cases.

The next point of importance is that there seems no statistical evidence that the "young adult" type of phthisis is affected to any extent by environment. In this respect it would seem to resemble scarlet fever, as in the case of this disease there is very little proof that in any individual city it is more common in the more crowded parts than in the better class parts of the town. Such a distribution of the disease may be the case for a certain time, but so far as my observations go there is not a general phenomenon. When definitely spread by milk notoriously the opposite phenomenon is found inasmuch as the percentage of cases depend on the amount of milk drunk, and that amount is larger among the better class than among the poor. The "young adult" form of phthisis seems to obey the same law being as common in better class localities as in poorer ones. The number of cases of

* Loc. cit., p. 106.

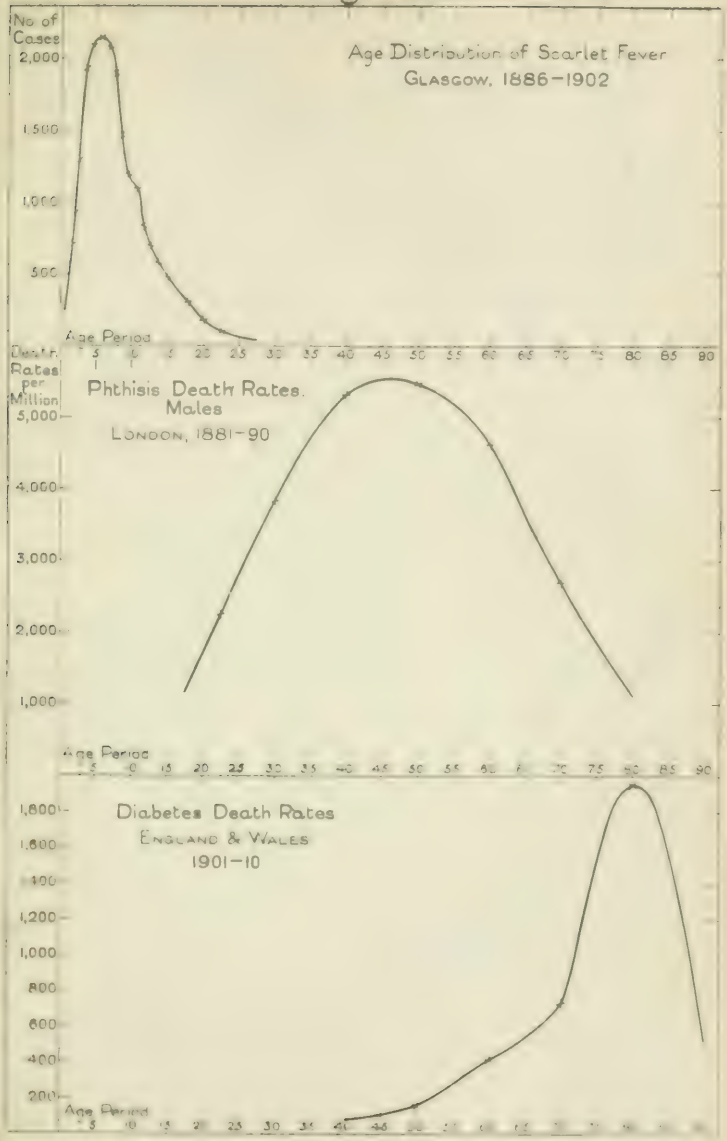
this type which occur in eminently healthy houses is quite surprising, as is within the immediate cognizance of every physician who practises in a district in which the "early type" of phthisis is prevalent.

The third point of importance seems to be that the epidemiology of the two chief types of phthisis, namely, the "young adult" and "middle age" types is different. Thus the present epidemic of phthisis among the young had its maximum somewhere about the middle of last century, while the epidemic of phthisis among the middle-aged had its maximum fully one hundred years ago. There is no doubt that a considerable part of the decline of phthisis in recent years is in line with the biological properties of diseases in general, and has little to do with hygienic conditions.

The fourth conclusion which may certainly be drawn, if the discussion in the preceding pages is correct, relates to the arguments which are based on the alteration which has taken place in the mean age at which death from phthisis occurs. It has been argued that because the mean age at death from phthisis has been steadily rising the population has become more immune, either on the ground of elimination of the susceptible persons or on the ground of better hygienic conditions.

Such an argument of course can be easily advanced, and as it looks *a priori* probable it is difficult to confute. However, such a rise in the mean age necessarily follows if the type of phthisis which is disappearing most rapidly is that among the "young adult," as has been shown to be probably the case. This point is simply mentioned: it will be fully discussed at some early date.

Diagram I


No of Cases
2,000
1,500
1,000
500
Age Distribution of Scarlet Fever
Glasgow, 1886–1902
Age Period
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90
Death Rates per Million
5,000
4,000
3,000
2,000
1,000
Phthisis Death Rates.
Males
London, 1881–90
Age Period
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90
1,800
1,600
1,400
1,200
1,000
800
600
400
200
Diabetes Death Rates
England & Wales
1901–10
Age Period
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90

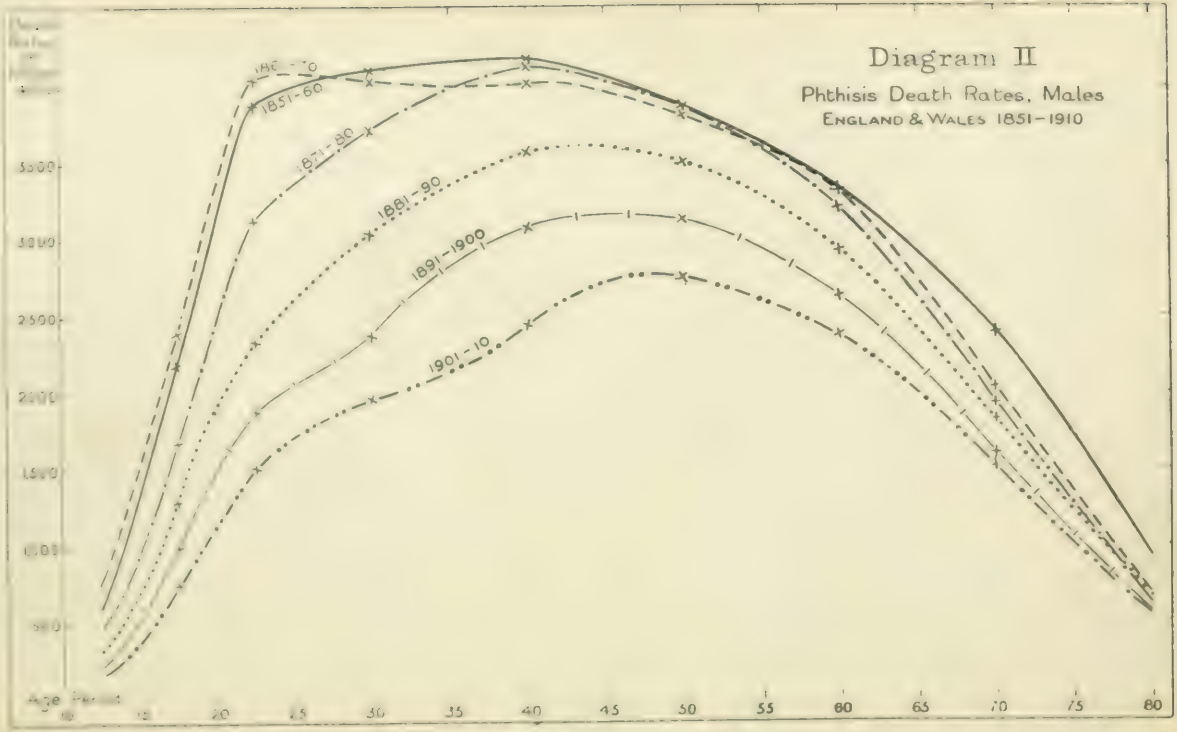


Diagram II
Phthisis Death Rates, Males
England & Wales 1851–1910
1851–60
1871–80
1881–90
1891–1900
1901–10
3000
2500
2000
1500
20
25
30
35
40
45
50
55
60
65
70
75
80

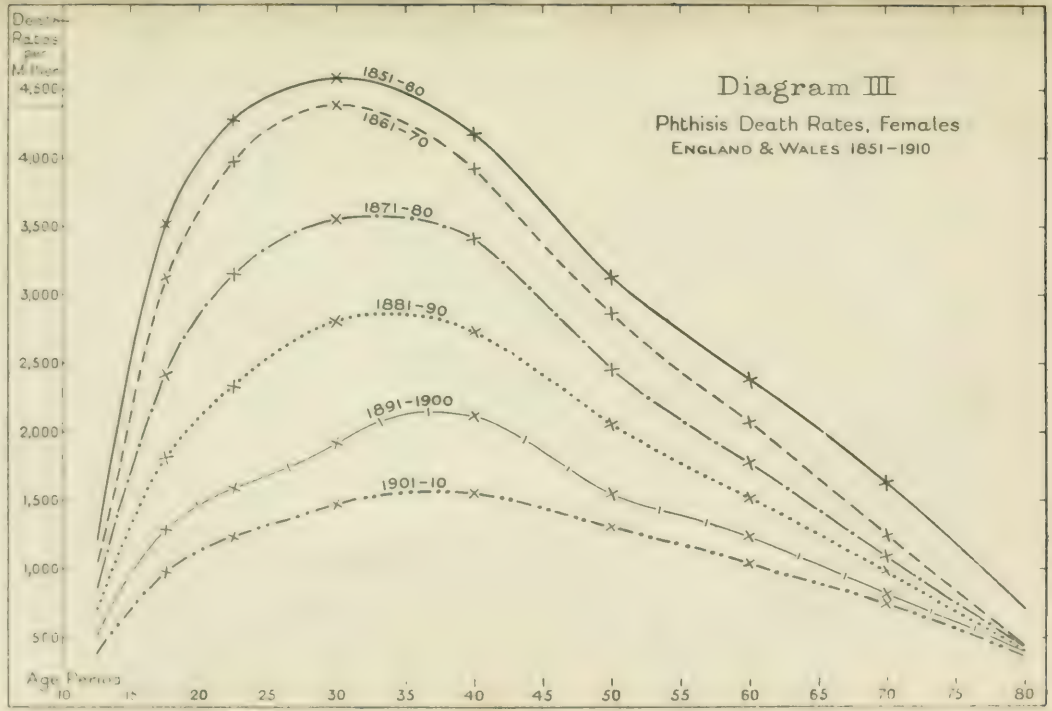


Diagram III
Phthisis Death Rates, Females
England & Wales 1851–1910
1851–80
1861–70
1871–80
1881–90
1891–1900
1901–10
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80

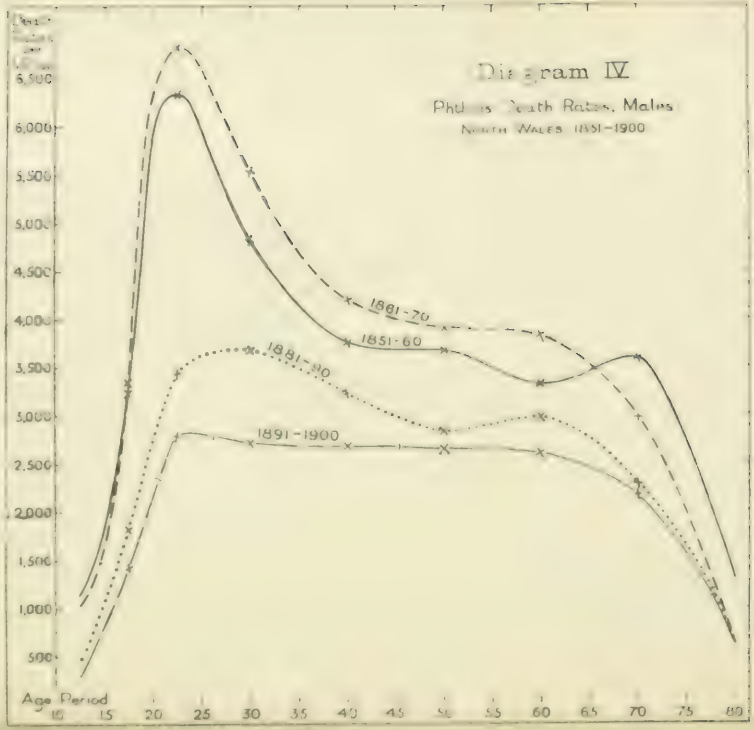
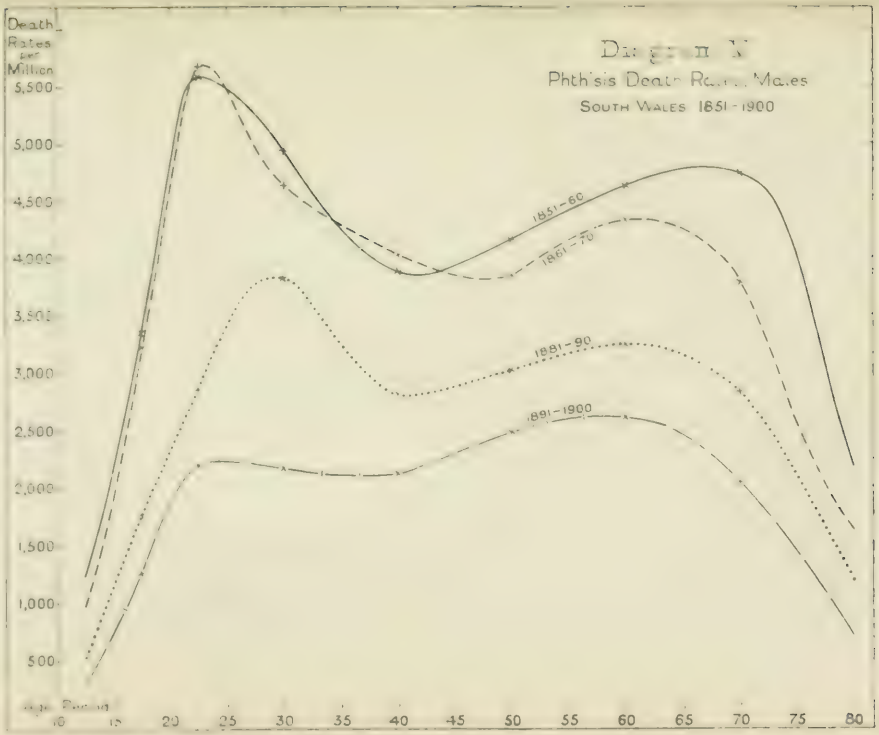


Diagram IV.
Phthisis Death Rates, Males
New South Wales 1851-1900
6,500
6,000
5,500
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
1851-60
1881-90
1891-1900
Age Period
15
20
25
30
35
40
45
50
55
60
65
70
75
80


Death Rates per Million
5,500
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
15
20
25
30
35
40
45
50
55
60
65
70
75
80
1851-60
1861-70
1881-90
1891-1900
Phthisis Death Rates Males
South Wales 1851-1900

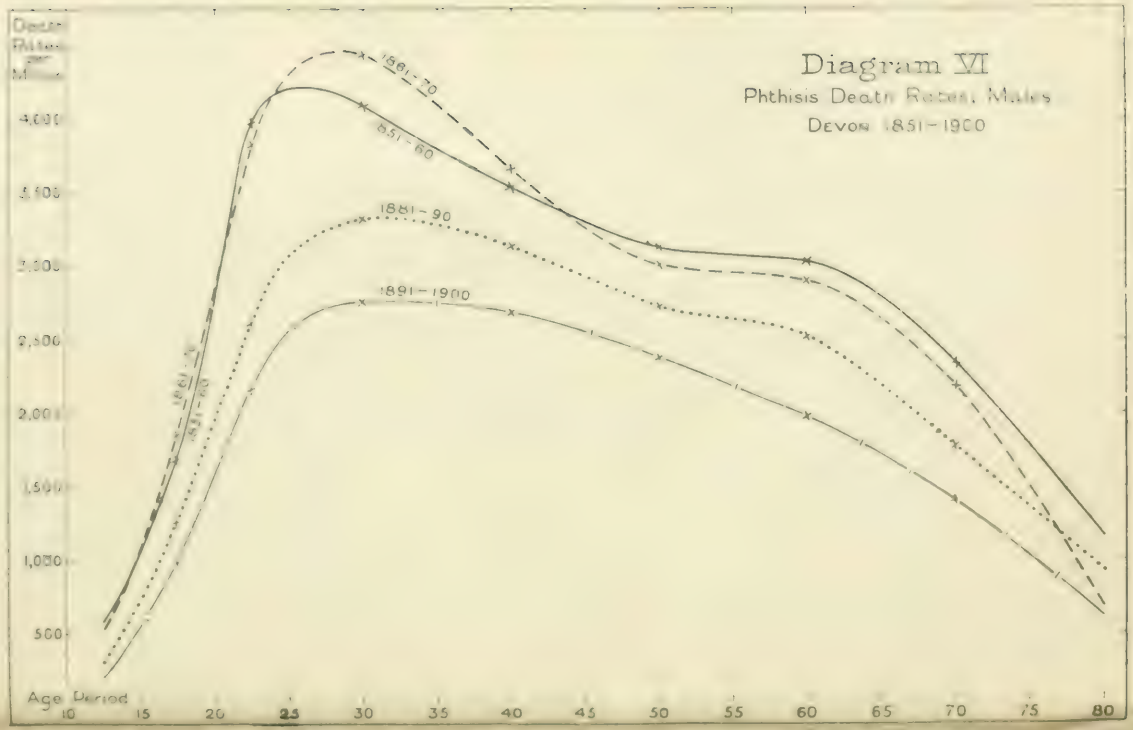


Diagram VI
Phthisis Death Rates. Males
Devon 1851–1900
1861–70
1851–60
1881–90
1891–1900
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
Age Period
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80

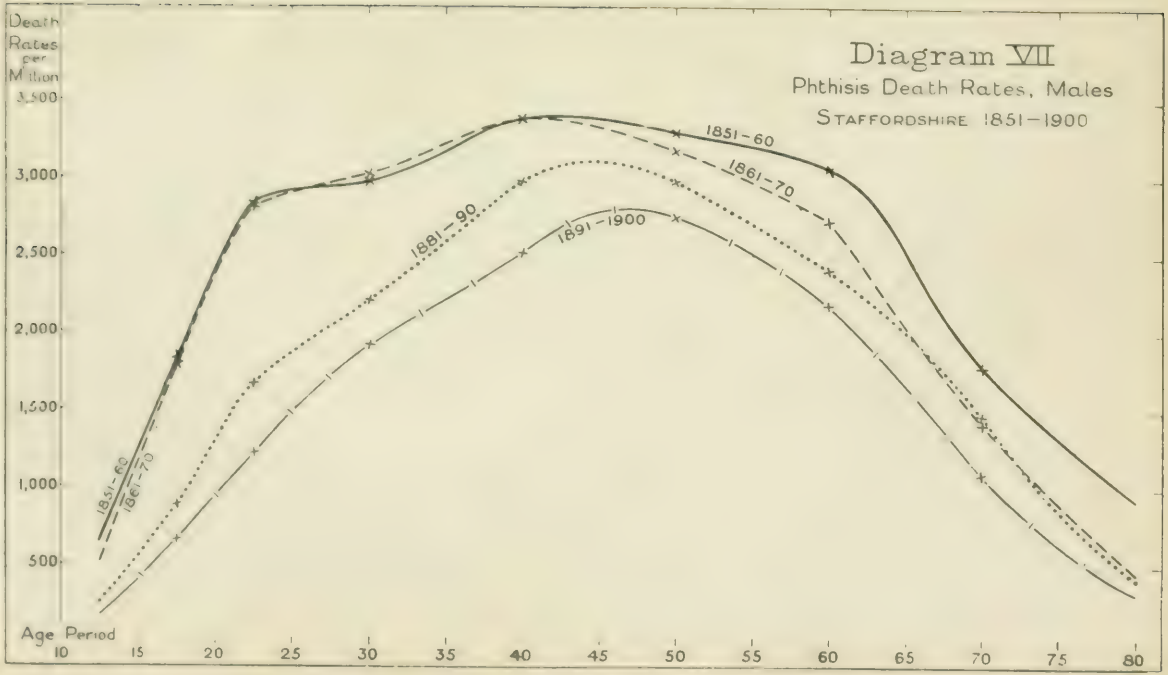


Diagram VII
Phthisis Death Rates, Males
STAFFORDSHIRE 1851–1900
Death Rates per Million
3,500
3,000
2,500
2,000
1,500
1,000
500
1851–60
1861–70
1881–90
1891–1900
Age Period
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80

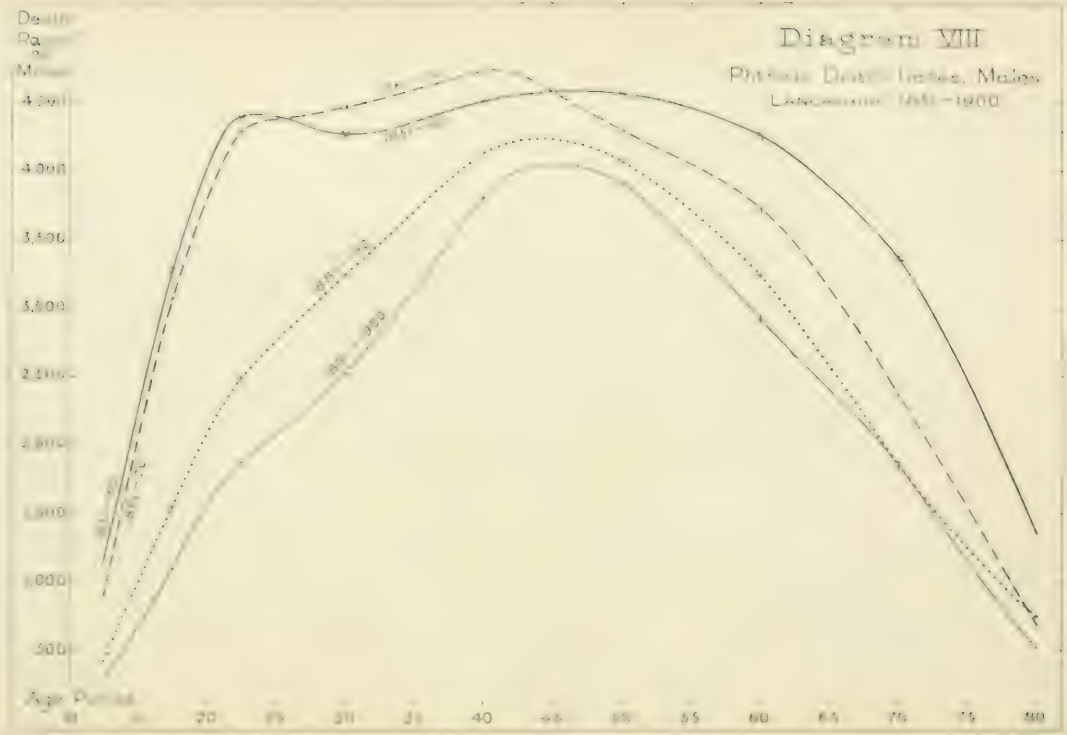


Diagram VIII
Phthisis Death-rates, Males
Lancashire 1851–1900
Death-Rate per Million
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
Age Period
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85

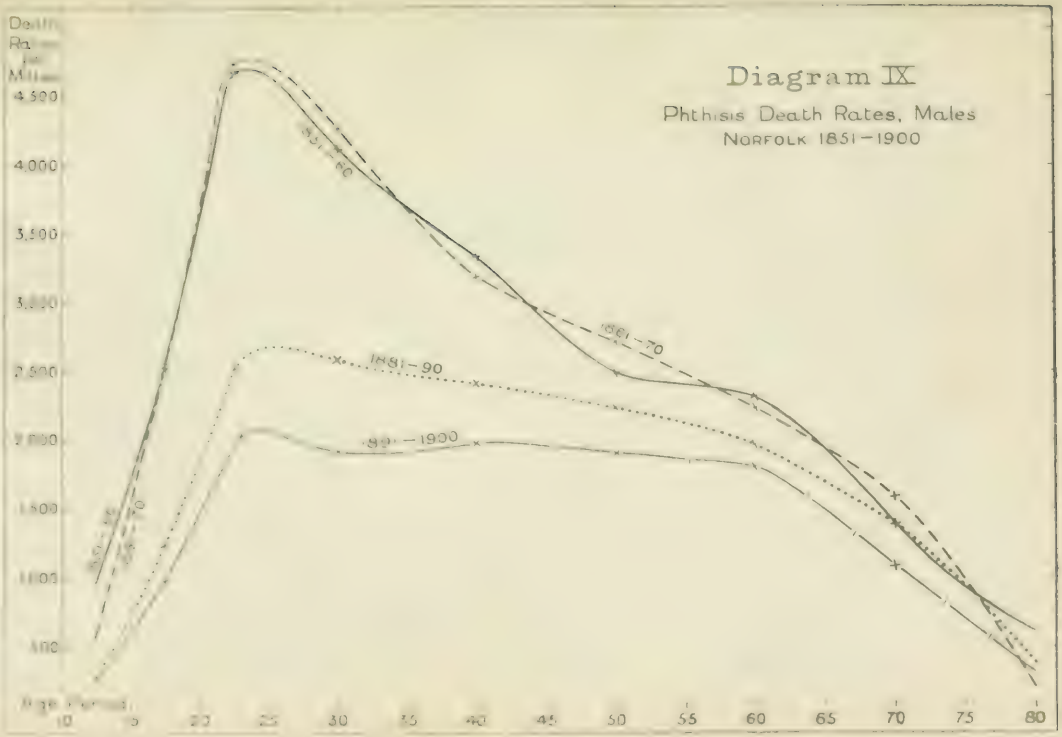


Diagram IX
Phthisis Death Rates, Males
Norfolk 1851–1900
4,500
4,000
3,500
1881–90
1891–1900
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80

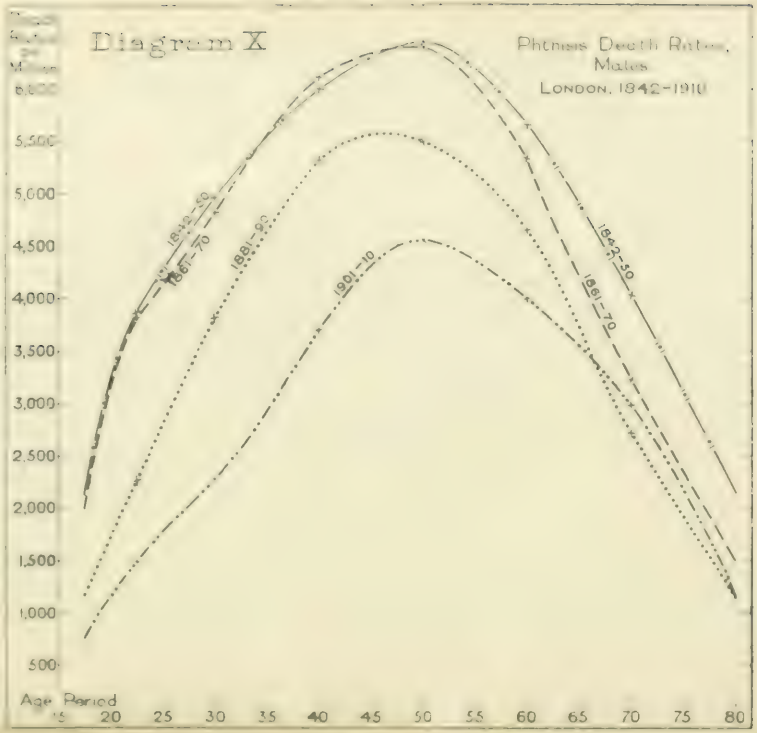


Diagram X
Phthisis Death Rates,
Males
London, 1842-1910
6,000
5,500
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
1842-50
1861-70
1881-90
1901-10
1842-50
1861-70
Age Period
20
25
30
35
40
45
50
55
60
65
70
75
80

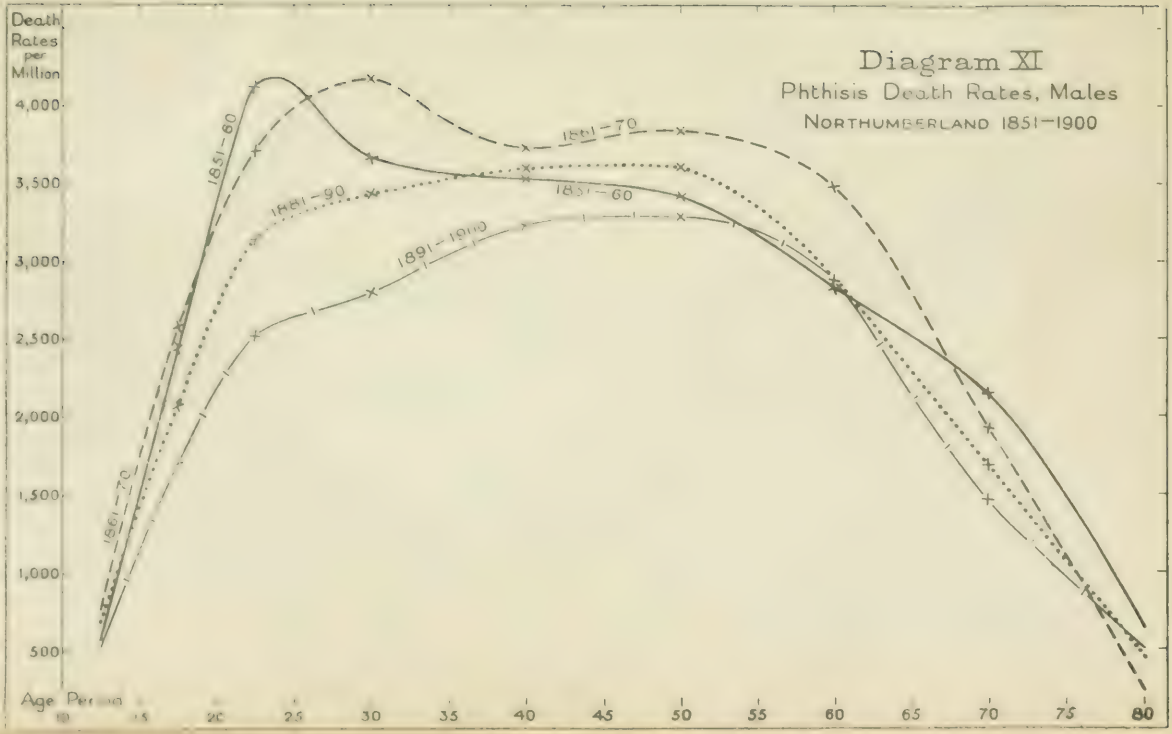


Diagram XI
Phthisis Death Rates, Males
NORTHUMBERLAND 1851—1900
Death Rates per Million
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
1851—60
1861—70
1881—90
1891—1900
1851—60
1861—70
Age Periods
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80

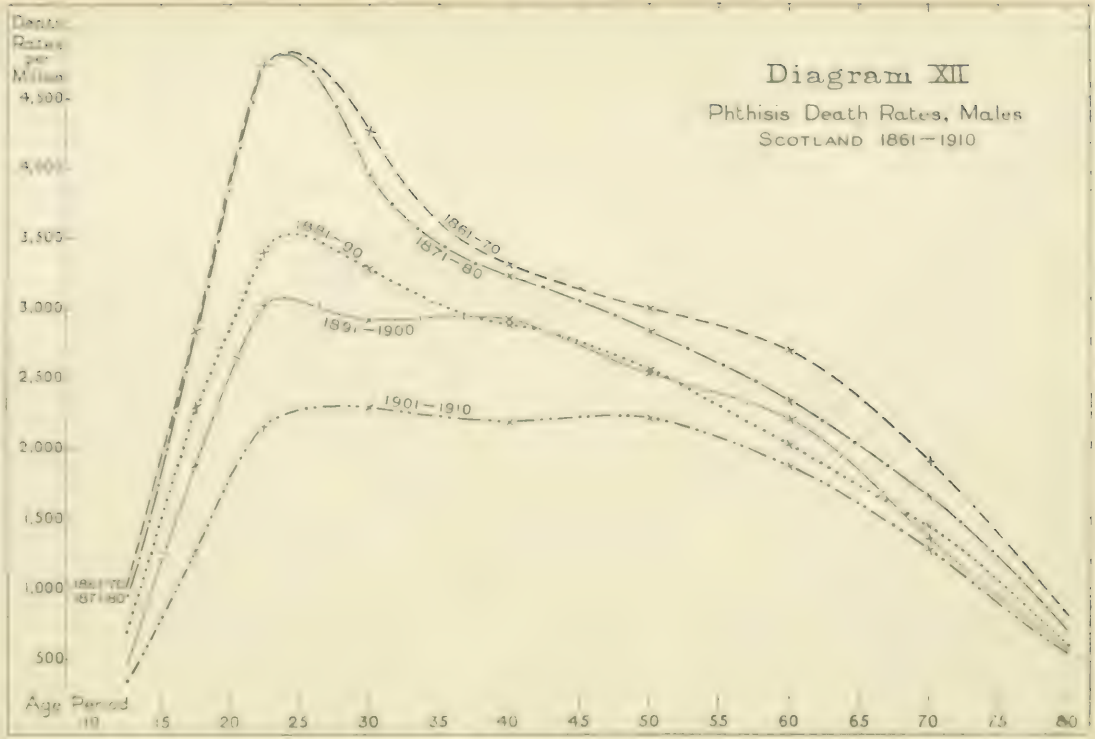
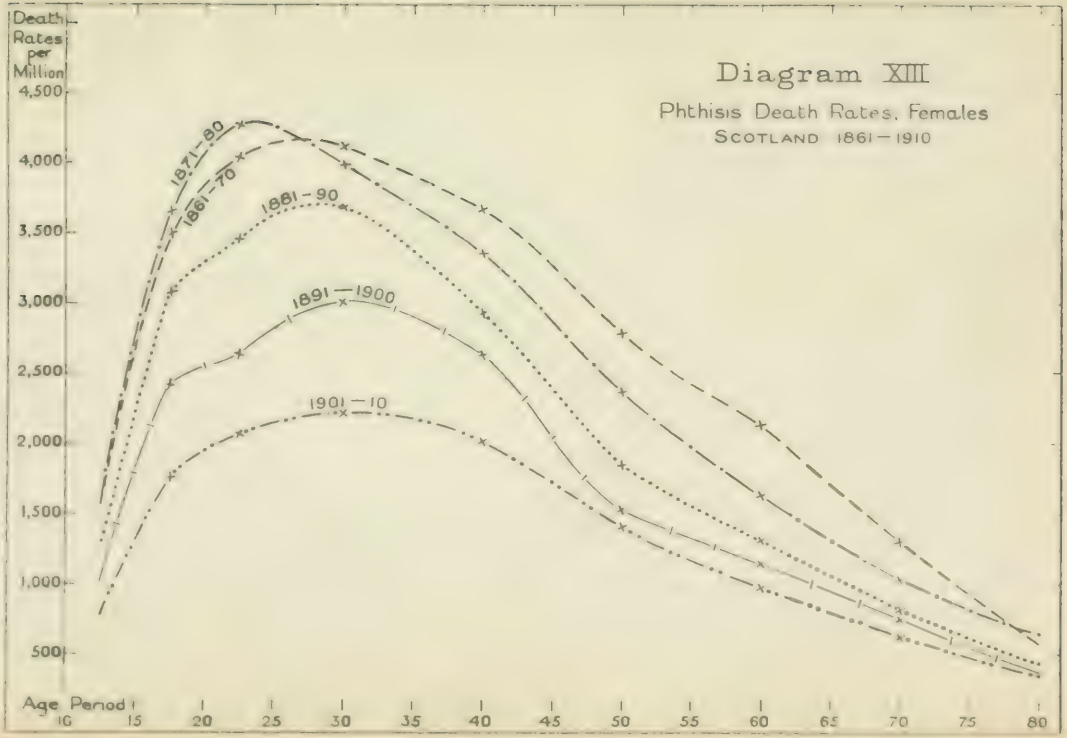
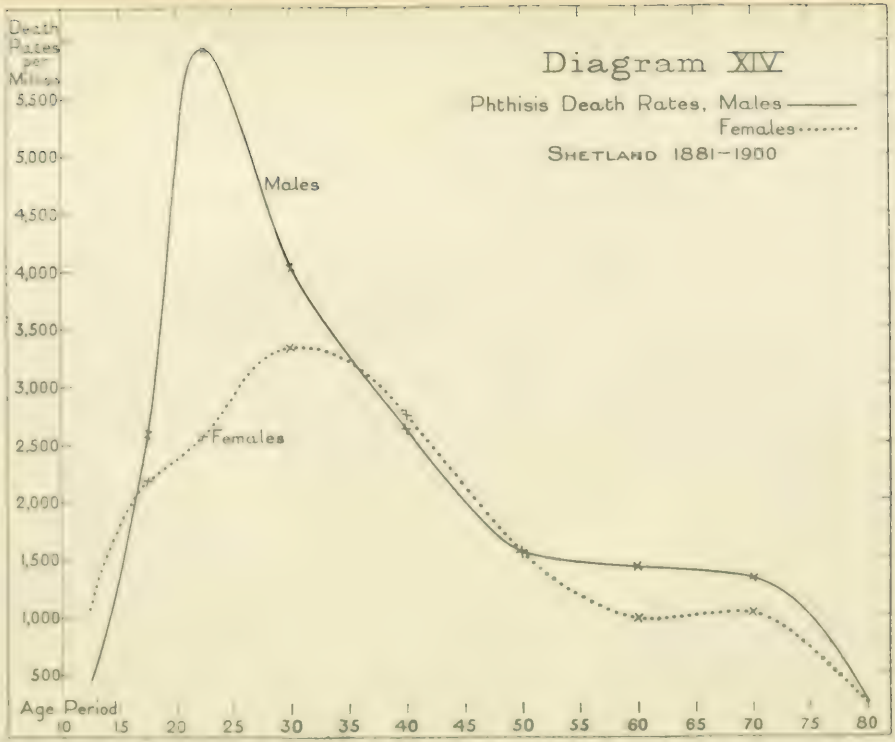
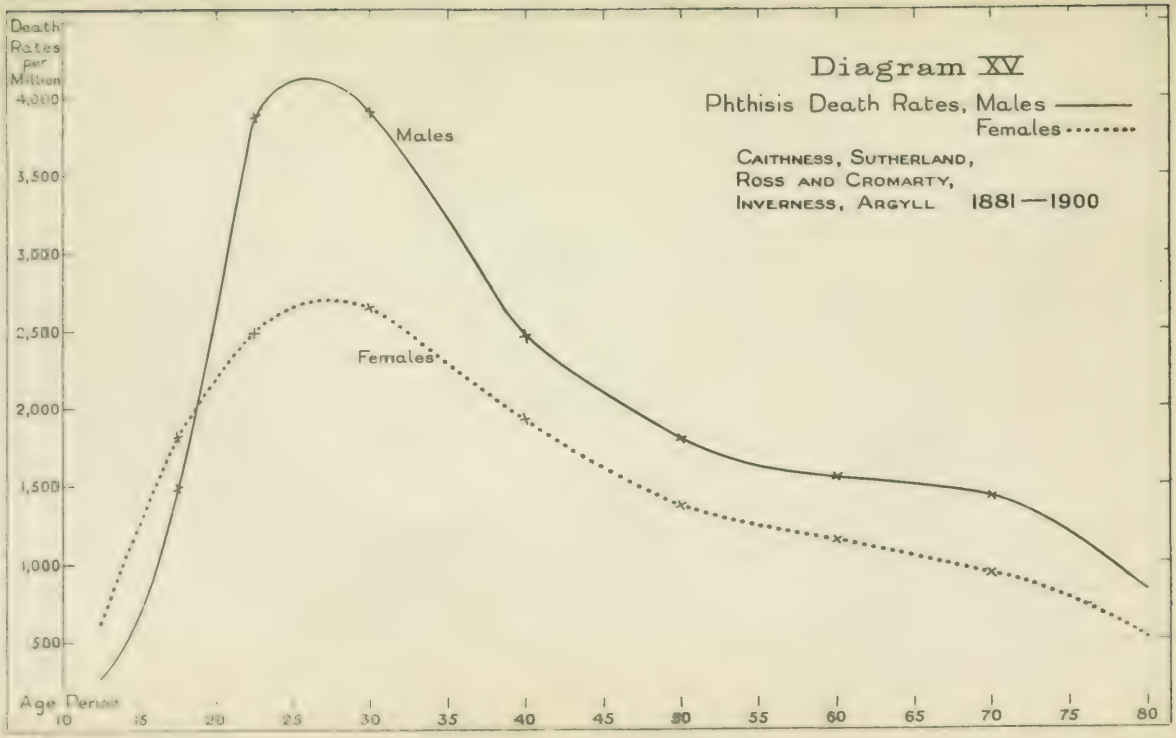
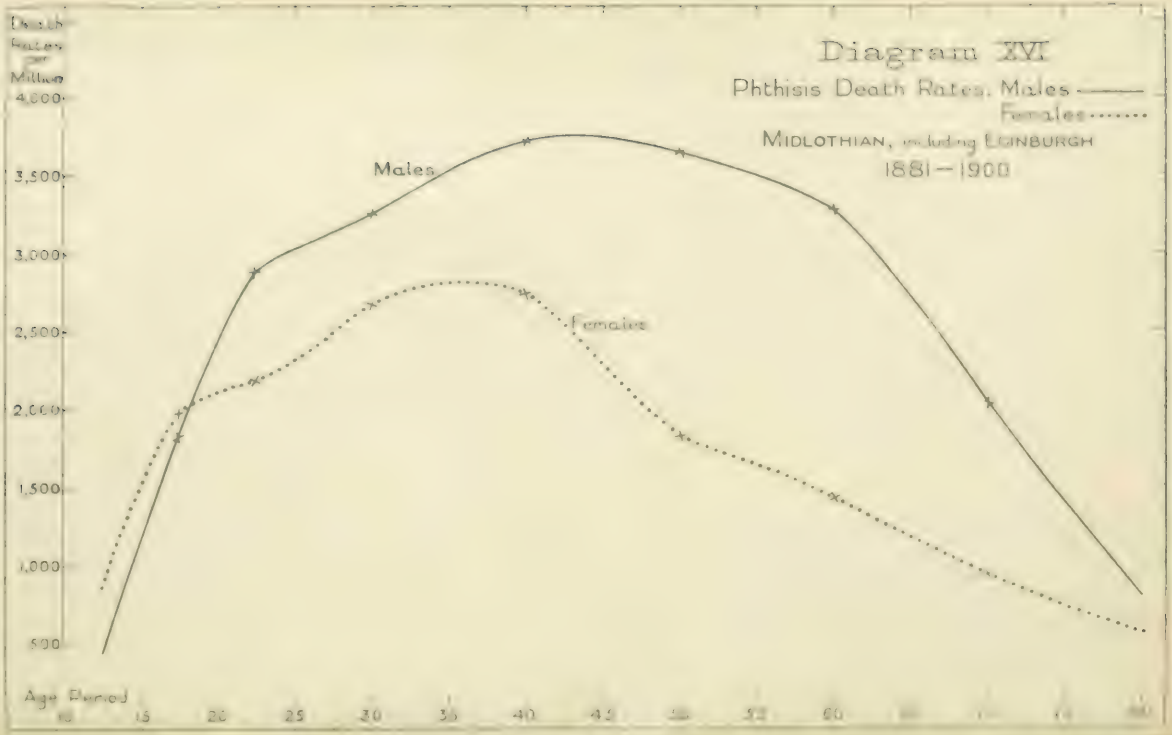


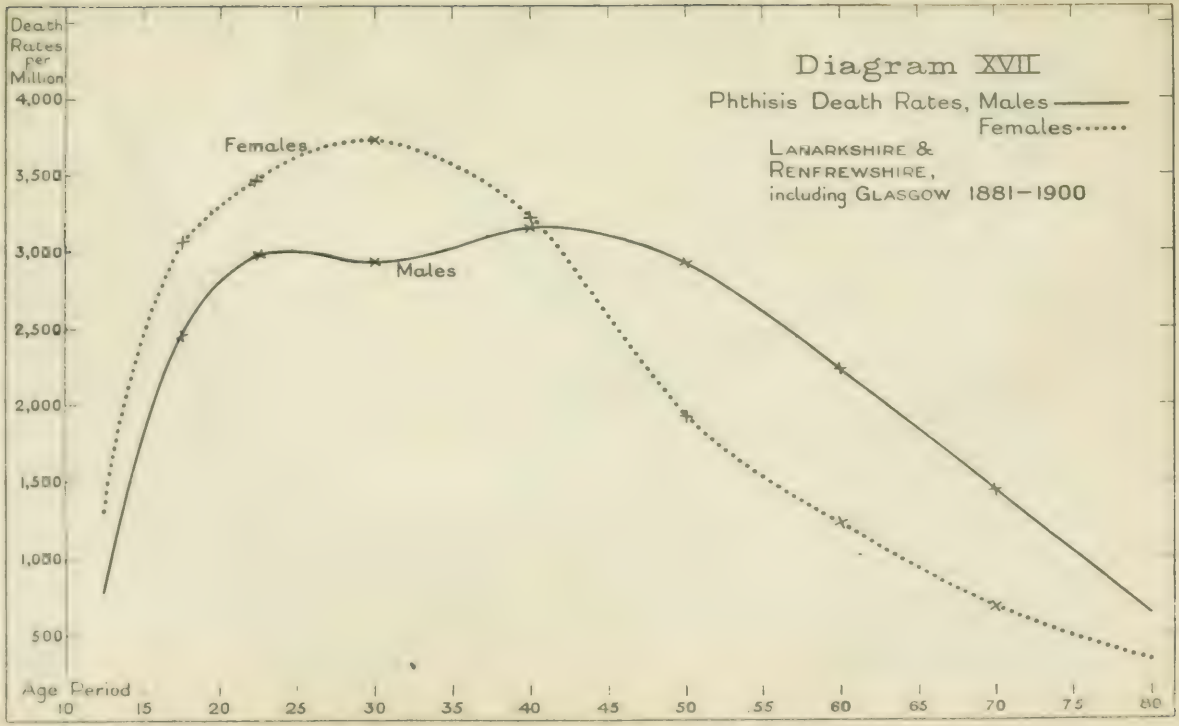
Diagram XII
Phthisis Death Rates, Males
Scotland 1861—1910
Death Rates per Million
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
1861-70
1871-80
1881-90
1891-1900
1901-1910
Age Period
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80


Death Rates per Million
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
Diagram XIII
Phthisis Death Rates. Females
Scotland 1861—1910
1871—80
1861—70
1881—90
1891—1900
1901—10
Age Period
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80


Death Rates per Million
5,500
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
Diagram XIV
Phthisis Death Rates, Males ——
Females ·····
SHETLAND 1881–1900
Males
Females
Age Period
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80


Death Rates per Million
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
Age Periods
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
Diagram XV
Phthisis Death Rates, Males ——— Females .....
Caithness, Sutherland, Ross and Cromarty, Inverness, Argyll 1881—1900
Males
Females


Death Rates per Million
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
Age Period
15
20
25
30
35
40
Diagram XVI
Phthisis Death Rates. Males ——— Females .....
MIDLOTHIAN, including EDINBURGH
1881—1900
Males
Females


Death Rates per Million
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
Age Period
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
Females
Males
Diagram XVII
Phthisis Death Rates, Males ——— Females ·····
Lanarkshire & Renfrewshire, including Glasgow 1881–1900

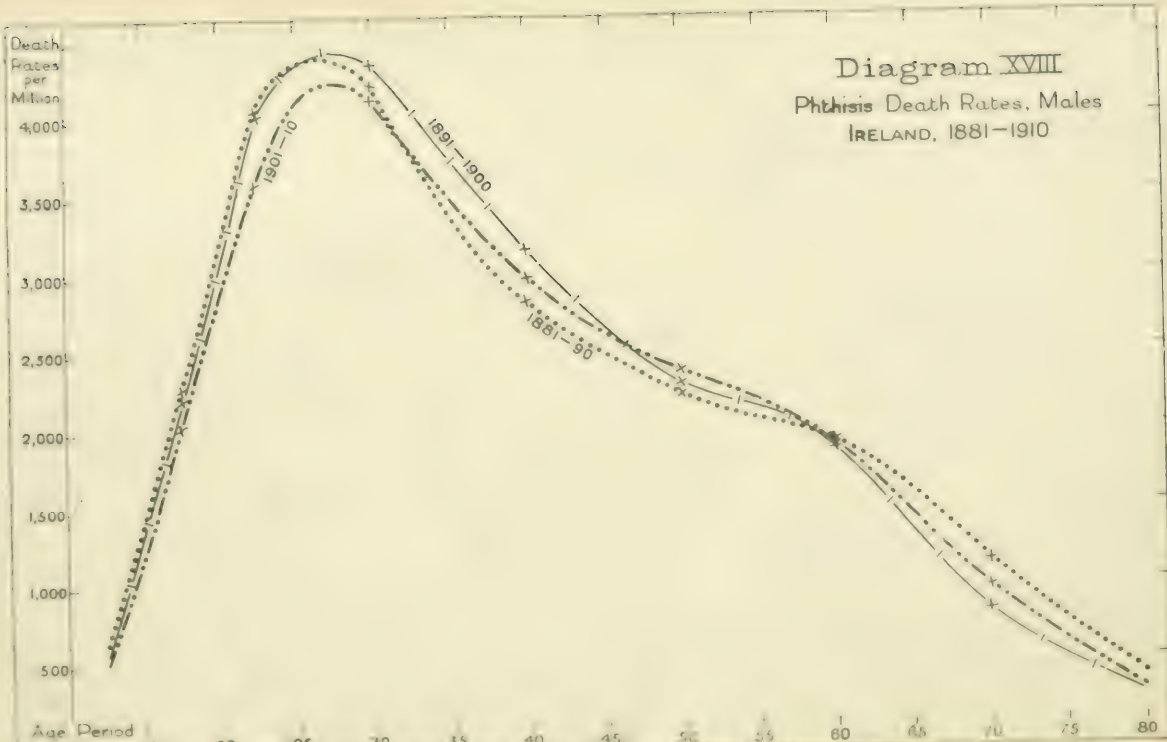
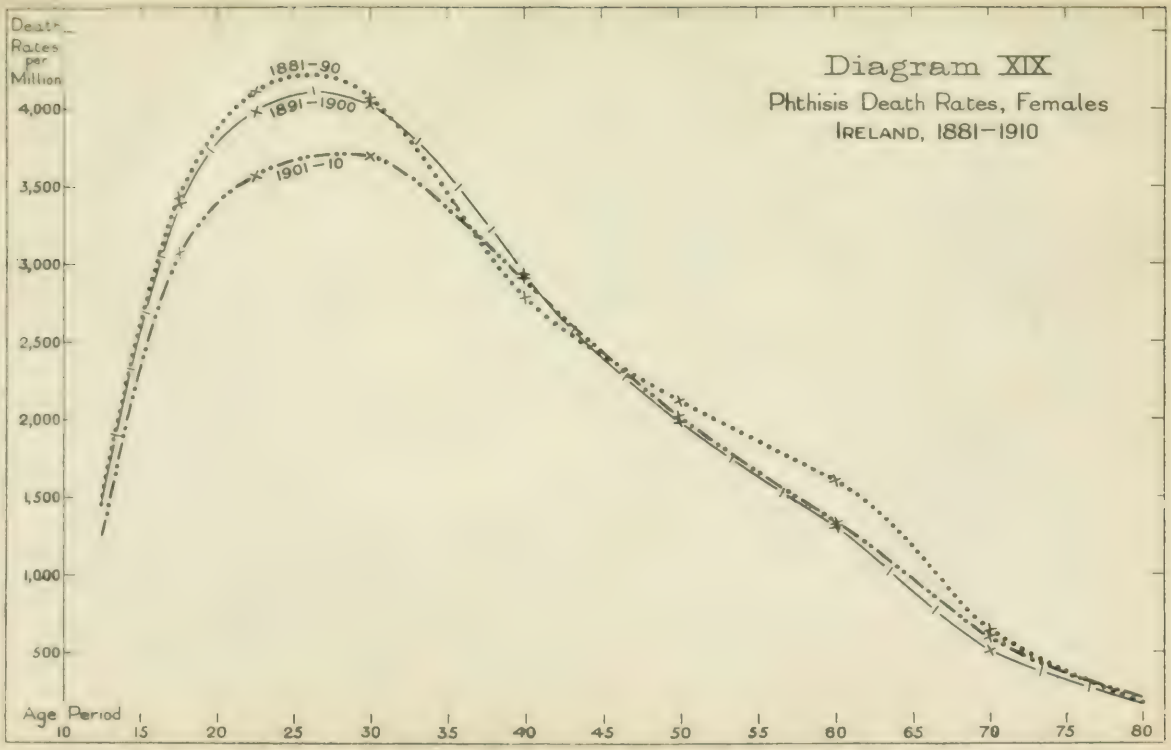
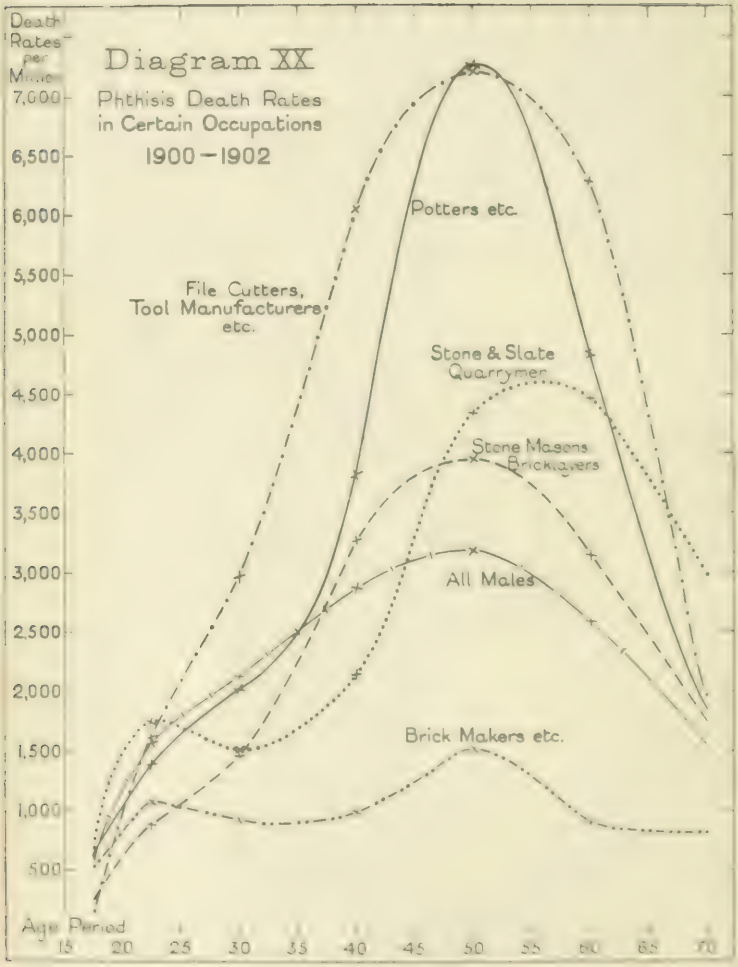
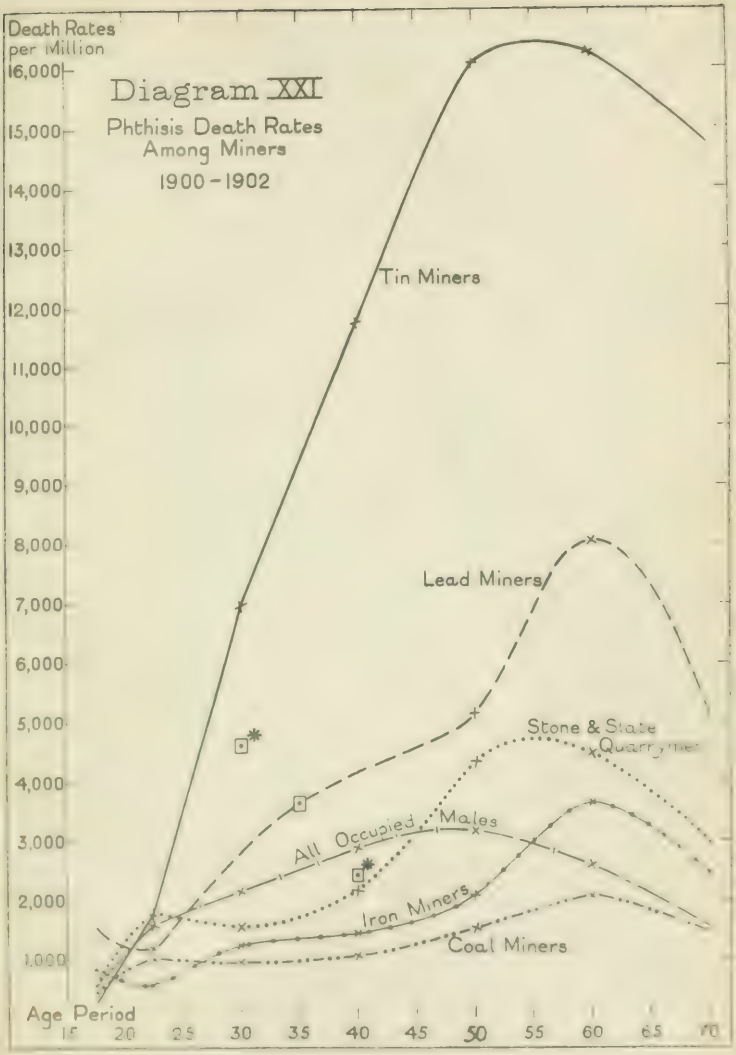


Diagram XVIII
Phthisis Death Rates, Males
IRELAND, 1881–1910
Death Rates per Million
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
1901–10
1891–1900
1881–90
Age Period
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80


Death Rates per Million
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
1881–90
1891–1900
1901–10
Age Period
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
Diagram XIX
Phthisis Death Rates, Females
Ireland, 1881–1910


Death Rates per Million
Diagram XX
Phthisis Death Rates in Certain Occupations
1900—1902
7,000
6,500
6,000
5,500
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
Potters etc.
File Cutters, Tool Manufacturers etc.
Stone & Slate Quarrymen
Stone Masons Bricklayers
All Males
Brick Makers etc.
Age Period
15
20
25
30
35
40
45
50
55
60
65
70


Death Rates per Million
Diagram XXI
Phthisis Death Rates Among Miners 1900-1902
16,000
15,000
14,000
13,000
12,000
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
Tin Miners
Lead Miners
Stone & Slate Quarrymen
All Occupied Males
Iron Miners
Coal Miners
Age Period
15
20
25
30
35
40
45
50
55
60
65
70

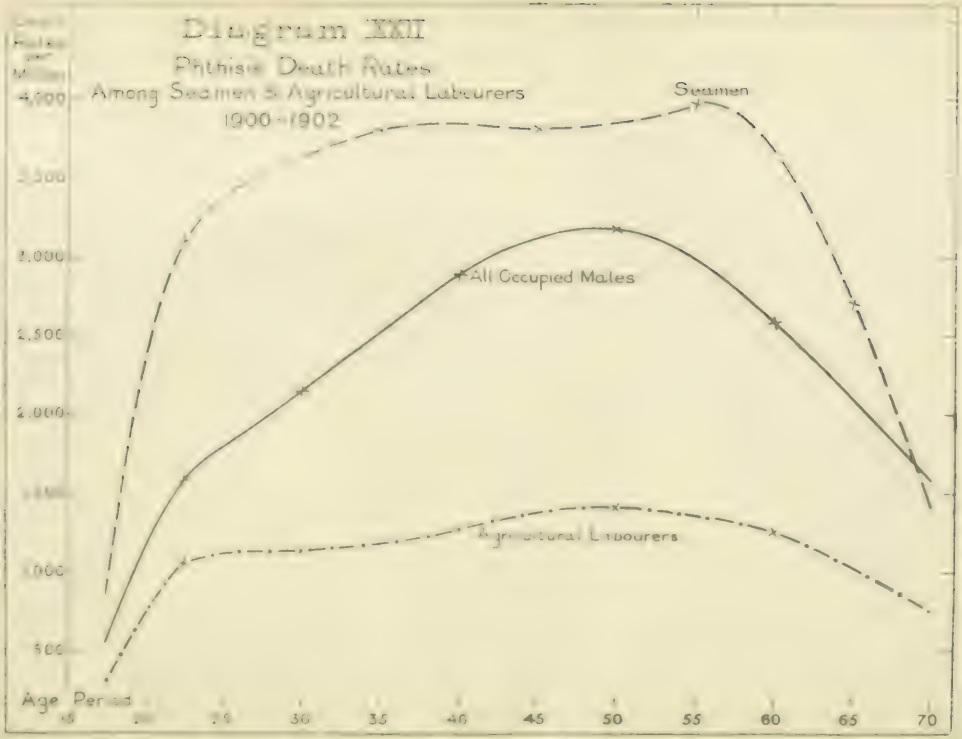
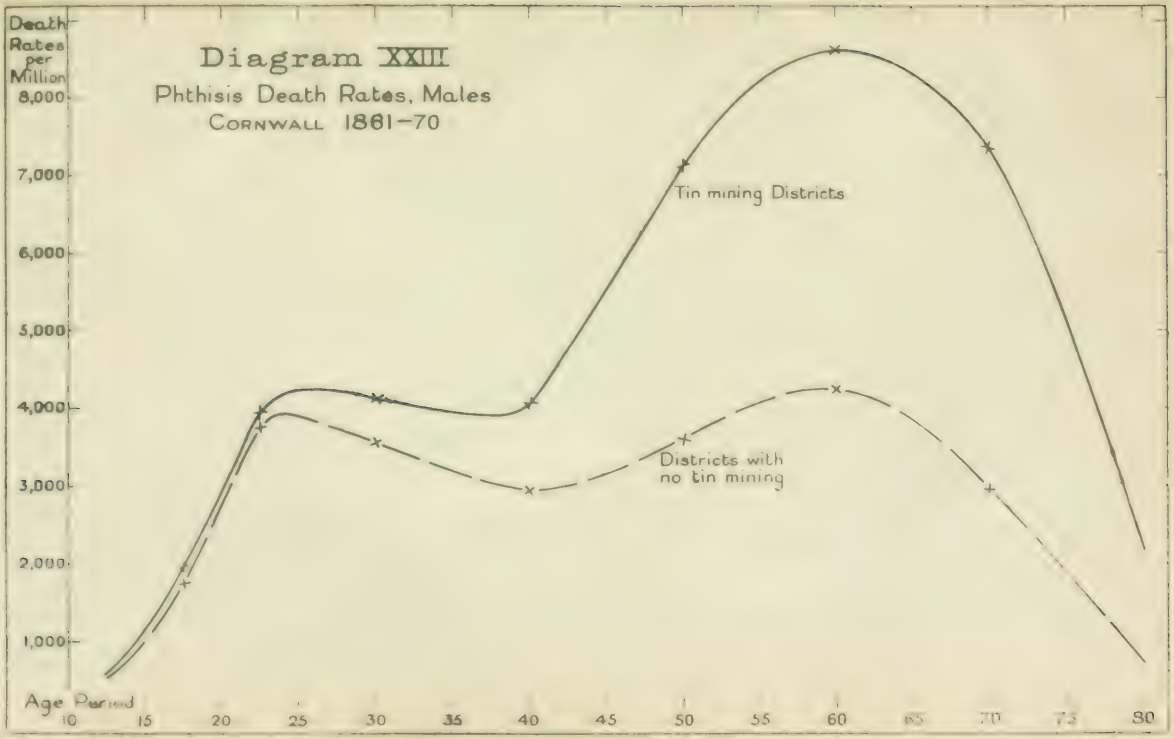
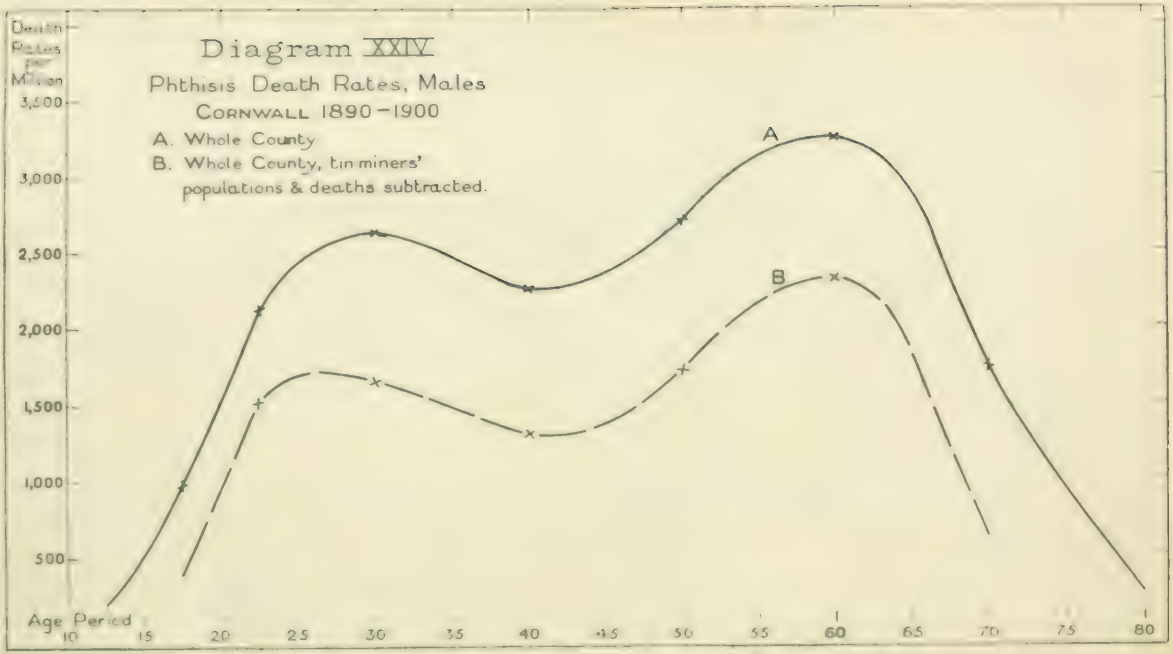


Diagram XXII
Phthisis Death Rates
Among Seamen & Agricultural Labourers
1900-1902
Seamen
All Occupied Males
Agricultural Labourers
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
Age Period
15
20
25
30
35
40
45
50
55
60
65
70


Death Rates per Million
Diagram XXIII
Phthisis Death Rates, Males
Cornwall 1861–70
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
Tin mining Districts
Districts with no tin mining
Age Period
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80


Death Rates per Million
Diagram XXIV
Phthisis Death Rates, Males
CORNWALL 1890–1900
A. Whole County
B. Whole County, tin miners' populations & deaths subtracted.
A
B
3,500
3,000
2,500
2,000
1,500
1,000
500
Age Period
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80

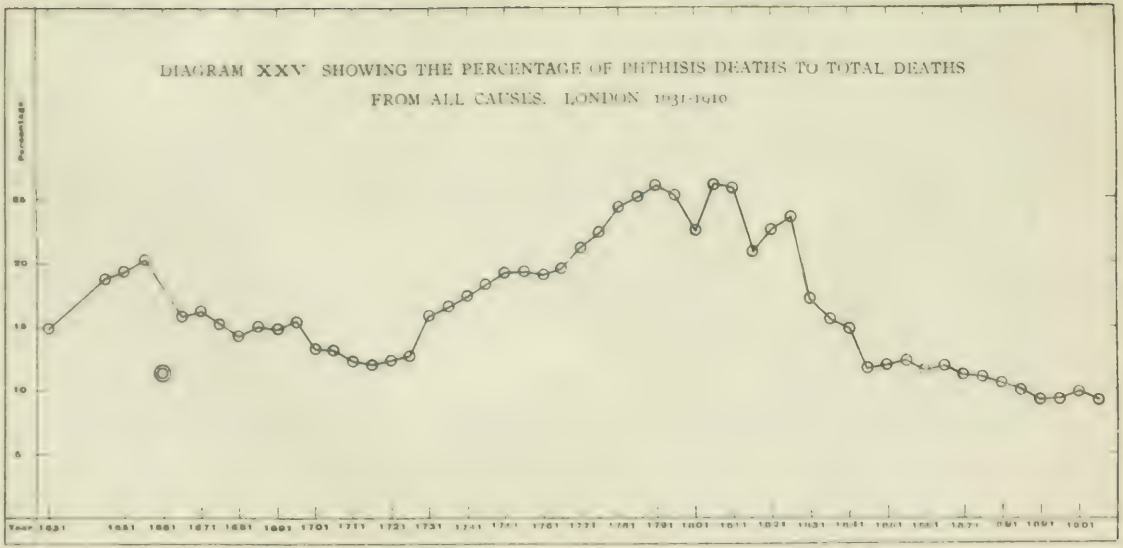
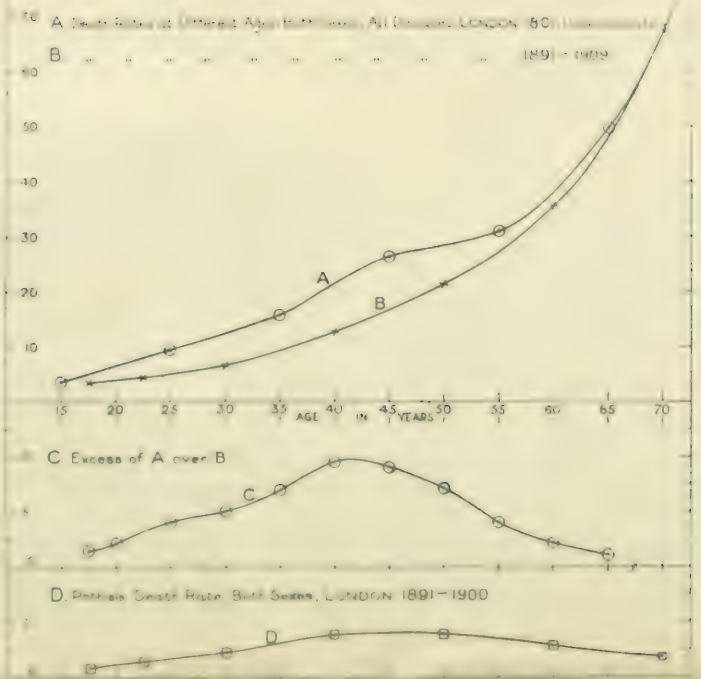


DIAGRAM XXV SHOWING THE PERCENTAGE OF PHTHISIS DEATHS TO TOTAL DEATHS
FROM ALL CAUSES. LONDON 1631-1910
Percentage
25
20
15
10
5
Year 1631
1651
1661
1671
1681
1691
1701
1711
1721
1731
1741
1751
1761
1771
1781
1791
1801
1811
1821
1831
1841
1851
1861
1871
1881
1891
1901

Diagram XXII.



N.B. C & D are on the scale of A & B.

NATIONAL HEALTH INSURANCE.

MEDICAL RESEARCH COMMITTEE.

Reports of the Special Committee upon the Standardisation of Pathological Methods.

THE LABORATORY DIAGNOSIS OF GONOCOCCAL INFECTIONS.

METHODS FOR THE DETECTION OF SPIROCHAETES.

LONDON:
PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE.
To be purchased directly or through any Bookseller from
H.M. STATIONERY OFFICE at the following addresses:
DRURY LANE, LONDON, W.C. 2, and
28, ABINGDON STREET, LONDON, S.W.1;
37, PETER STREET, MANCHESTER;
1, ST. ANDREW'S CRESCENT, CARDIFF;
23, FORTH STREET, EDINBURGH;
or from E. PONSONBY, LTD., 116, GRAFTON STREET, DUBLIN.

1918.

Price 1s. *Net.*

MEDICAL RESEARCH COMMITTEE.

The following publications relating to the work of the Medical Research Committee can be purchased through any bookseller, or directly from H.M. Stationery Office, at the following addresses: Imperial House, Kingsway, London, W.C. 2, and 28, Abingdon Street, London, S.W. 1; 37, Peter Street, Manchester; 1, St. Andrew's Crescent, Cardiff; 23, Forth Street, Edinburgh; or from E. Ponsonby, Ltd., 116, Grafton Street, Dublin.

First Annual Report of the Medical Research Committee, 1914-1915. [Cd. 8101.] Price 4*d*., post free 4*d*.

Second Annual Report of the Medical Research Committee, 1915-1916. [Cd. 8399.] Price 3½*d*., post free 5*d*.

Third Annual Report of the Medical Research Committee. [Cd. 8825.] Price 6*d*., post free 7*d*.

Special Report Series.

No. 1. First Report of the Special Investigation Committee upon the Incidence of Phthisis in relation to Occupations. The Boot and Shoe Trade. Price 3*d*., post free 4*d*.

No. 2. Report of the Special Advisory Committee upon Bacteriological Studies of Cerebro-spinal Fever during the Epidemic of 1915. Price 6*d*., post free 7½*d*.

No. 3. Bacteriological Studies in the Pathology and Preventive Control of Cerebro-spinal Fever among the Forces during 1915 and 1916. Price 1s. 6*d*., post free 1s. 8½*d*.

No. 4. Reports upon Investigations in the United Kingdom of Dysentery cases received from the Eastern Mediterranean.
I. Amœbic Dysentery and the Protozoological Investigation of Cases and Carriers. Price 1s., post free 1s. 2*d*.

No. 5. II. Report upon 878 Cases of Bacillary Enteritis. Price 1s. 6*d*., post free 1s. 8*d*.

No. 6. III. Report upon recovered Cases of Intestinal Disease in the Royal Naval Hospital, Haslar, 1915-16.
IV. Report upon combined Clinical and Bacteriological Studies of Dysentery Cases from the Mediterranean. Price 1s. 6*d*., post free 1s. 8*d*.

No. 7. V. Report upon 2,360 Enteritis "Convalescents" received at Liverpool from various Expeditionary Forces. Price 2s., post free 2s. 2½*d*.

MEDICAL RESEARCH COMMITTEE.

REPORTS

OF THE

SPECIAL COMMITTEE UPON THE STANDARDISATION OF PATHOLOGICAL METHODS.

No. 2. THE LABORATORY DIAGNOSIS OF GONOCOCCAL INFECTIONS.

No. 3. METHODS FOR THE DETECTION OF SPIROCHAETES.

Approved for publication by the Medical Research Committee, 7th June, 1918.

Medical Research Committee.

National Health Insurance.

The Hon. WALDORF ASTOR, M.P. (*Chairman*).

The Right Hon. CHRISTOPHER ADDISON, M.D., M.P.

The VISCOUNT GOSCHEN, C.B.E. (*Treasurer*).

C. J. BOND, C.M.G., F.R.C.S. (Hon. Colonel).

A. K. CHALMERS, M.D., D.P.H. (Lieut.-Colonel R.A.M.C. (T.)).

PROFESSOR WILLIAM BULLOCH, M.D., F.R.S.

PROFESSOR F. G. HOPKINS, D.Sc., F.R.S.

COLONEL SIR WILLIAM LEISHMAN, K.C.M.G., C.B., F.R.S.

PROFESSOR G. R. MURRAY, M.D., F.R.C.P. (Major R.A.M.C. (T.)).

SIR WALTER M. FLETCHER, K.B.E., M.D., F.R.S. (*Secretary*).

In April, 1917, the Medical Research Committee invited the following special Committee to consider how far it may be practicable and desirable to obtain the standardisation of routine pathological methods, and to report to them. The special Committee were empowered to co-opt additional members for particular divisions of their subject.

LIEUT.-COLONEL J. G. ADAMI, M.D., F.R.S., C.A.M.C.

MAJOR F. W. ANDREWES, M.D., F.R.S., R.A.M.C., T.

PROFESSOR WILLIAM BULLOCH, M.D., F.R.S.

For the consideration of the subjects dealt with in the two Reports now presented the Special Committee invited the co-operation of COLONEL L. W. HARRISON, D.S.O., K.H.P., who by permission joined the Committee for this purpose.

REPORTS OF THE SPECIAL COMMITTEE UPON THE STANDARDISATION OF PATHOLOGICAL METHODS.

The Special Committee beg leave to present to the Medical Research Committee two reports upon subjects of great importance in the recognition of venereal disease—the laboratory diagnosis of gonococcal infections and the methods for the detection of spirochaetes. They have again to acknowledge gratefully the assistance given to them by Colonel L. W. Harrison, D.S.O., K.H.P., throughout their consideration of these subjects and the preparation of the reports. To other workers they are also greatly indebted for help in particular directions, as will appear in the text of the reports, and to all these they would express their gratitude here.

No. 2.—THE LABORATORY DIAGNOSIS OF GONOCOCCAL INFECTIONS.

CONTENTS.

	PAGE.
Introductory	3
I.—The Localities to be examined for the Presence of Gonococci	5
II.—Methods to be employed for the Microscopic Identification of the Gonococcus	6
III.—The Cultivation of the Gonococcus	8
IV.—Methods for the Production of a Focal Gonococcal Reaction	9
V.—The Complement Fixation Test	10
VI.—The Keeping of Records	14
Appendices	18

Introductory.

The Committee desire to call attention to the special difficulties associated with the diagnosis of gonococcal infections, and to recommend the employment of methods whereby the chance of incorrect diagnosis may be reduced to a minimum. Their action is prompted by a recognition of the increased call made upon the bacteriological laboratories of this country under the provisions of the Venereal Diseases Act. A wrong positive diagnosis may be the means of inflicting grave injury upon the individual; a wrong negative diagnosis is liable to injure the family of the individual and the community to an even greater extent.

The stage has not yet been reached at which a diagnosis can be made with certainty in all cases by bacteriological methods alone. There still remain cases of latent gonorrhœa, both in the male and in the female, which fail to react to any of the bacteriological tests at present at our disposal. In this as in any other infectious disease bacteriological evidence cannot always replace clinical. It is an adjunct, the value of which

is suggested to a considerable degree when the diagnosis is entrusted to a thoroughly trained bacteriologist employing the best methods. It is timely, therefore, to direct attention to what are the best methods and what are their limitations.

Cases presenting themselves for examination for the detection or elimination of gonococcal infection are to be divided into:

(1) Cases in the acute stage, actual or suspected.

(2) Cases in the late or chronic stage, with or without a history of previous acute gonococcal infection.

In the acute the history of an acute attack is usually obtainable; in the chronic this history or the acute stage is commonly wanting.

The bacteriological diagnosis of gonorrhœa is based in the first place upon the recognition of the gonococcus under the microscope. The picture presented in films, made from the discharge obtained in a frank case of acute gonorrhœa, is characteristic as regards the intracellular position of the gonococci, their morphology and staining, and these ordinary cases present no difficulty. In those, however, that are clinically doubtful or suspicious, the bacteriologist can render valuable aid. In these cases the picture presented is apt to be atypical and the routine bacteriological technique must be such as to reduce to a minimum the likelihood of false diagnosis.

The Recognition of Gonococci in Films.

The Committee are of opinion that a positive diagnosis may be justified from microscopic examination of films alone:—

(i) When the clinical history and appearances are those of an acute gonorrhœa.

(ii) When the proper technique has been employed.

(iii) When the observer is so thoroughly familiar with the appearances of the gonococcus in stained films as to be beyond the danger of confusing other micrococci with it.

As an aid and a reminder, recognising that the danger of this confusion is very real, the Committee have considered it advisable to include in this report the accompanying plate of accurate coloured representations of gonococci as seen in films and of other micro-organisms which are apt to be present in discharges from the genito-urinary passages (*cf.* Plates I and II). For these reproductions they are indebted to Colonel Harrison, D.S.O., who selected and provided the material, and to Mr. S. A. Sewell who made the drawings.

Where, in the acute discharge, microscopical examination gives negative results, where the clinical history and appearances are doubtful, and where chronic gonorrhœa is indicated or suspected, microscopical examination alone is inadequate for diagnostic purposes, and its results must be supplemented by the cultural and other methods detailed below. It also has to be borne in mind that the gonococci, when eventually eliminated from the primary focus of the infection, may still persist in the tissues, that, in fact, there may be extensive without local discharge cases of arthritis that may develop months, and it may be years, after the primary infection, even though there has been no discharge. In this case of course neither microscopical nor cultural investigations at the external genito-urinary passages give positive results and an indirect method is required such as complement fixation.

I.—The localities to be examined for the presence of Gonococci.

For diagnostic purposes the acute stage of gonorrhœa with its abundant discharge, whether from the genito-urinary passages or the conjunctiva on ophthalmia, presents little or no difficulty in this connection. All that is necessary is to spread a film and make cultures of the abundant secretion which is usually available for the purpose.

In cases where there is little or no secretion the procedure is more difficult and the Committee are indebted to Dr. G. T. Western, of the London Hospital, who has a peculiarly large experience in cases of this kind, for a description of his method.

A. In the *Male* the gonococci may persist for long periods in:

i. A deep follicle in the anterior urethra, a para-urethral canal, Tyson's duct or in Cowper's glands.
ii. Behind a small, incomplete stricture.
iii. In the prostate or seminal vesicles.
iv. More rarely in the bladder or kidney.

Persistence in the first three regions may lead to the development of a chronic gleet, although chronic prostatic or vesicular infection may be present without any visible gleet.

The routine procedure should be as follows:

(a) The patient is to be instructed to present himself when he has held his water for 4 to 6 hours.

(b) The meatus should first be cleansed with an alcohol swab applied for about a minute, and an attempt then made to express secretion from the deeper part of the urethra. If this be present **films should be made.**

(c) Massage of the prostate, seminal vesicles and Cowper's glands, films being made of any secretion which appears at the meatus.

(d) Urine should then be passed, and the first ounce collected in a sterile tube. This is centrifuged, and the deposit examined, **smears and cultures being made.**

(e) Gonorrhœal infection of the bladder or either kidney demands the co-operation of a trained cystoscopist to procure samples of urine from the bladder and both ureters respectively, for the purpose of comparative study by films and cultures.

B. In the *Female* the gonococcus may be harboured for long periods in —

i. The urethra and para-urethral ducts.
ii. The glands of Bartholin.
iii. The cervix.
iv. The uterus and tubes.

Merely to examine a smear from the vulva is useless in the vulvo-vaginitis of children or adults, as other organisms than the gonococcus are often present.

Films and cultures should be obtained by the following procedures:

(a) The urethra should be examined for any discharge. After cleansing the meatus the urethral canal should be massaged forwards with the loop end of a fine hairpin through the anterior vaginal wall, or material may be secured by introducing the looped end of the hairpin into the urethra itself.

(*b*) The cervix should be exposed with a speculum. After cleansing with a swab, a platinum loop should be passed into the cervical canal. Menge's tube is useful for obtaining secretion from the cavity of the uterus as well as from the cervical canal.

(*c*) The contents of Bartholin's glands should be expressed.

There is evidence that in chronic cases positive results are more often obtained immediately after the menstrual period.

It is admitted that the above procedure, thorough and unobjectionable as it is, is of diagnostic value only when a positive result is obtained. A negative result does not eliminate the possibility that the gonococci are still in existence in other regions of the body, say, even in the regions examined by the bacteriologist. The gonococci, it is known, may be latent in epithelial cells, and while present may not be actively discharged at the period when the examination is made.

II.—Methods for the Identification of the Gonococci in Film Preparations.

1. *Diagnosis cannot be based wholly on the presence or absence of intracellular diplococci*, even if of characteristic bean shape, and this because—

(*a*) The diplococci of gonorrhœa need not be intracellular. All or almost all may be extracellular as in the very acute disease and in some cases of chronic gonorrhœa.

(*b*) The leucocytes escaping into discharges in the genito-urinary passages can take up other organisms which by simple stain methods are not distinguishable from gonococci.

The common practice of diagnosis by simple stain methods alone is, therefore, not permissible.

2. The gonococcus is a Gram-negative organism. The majority of micro-organisms which may be confused with it are Gram-positive. The only way to exclude these Gram-positive organisms is by the routine employment of the original Gram's method, or a reliable modification of it. For *official purposes* microscopical diagnosis *of the gonococcus must be by Gram's method*. The limitations in this method are discussed below.

Gram's Method.

In the course of years considerable variation has developed in different laboratories in carrying out the technique of staining by Gram's method.

The original recommendation of Gram[1] consisted in staining with Ehrlich's aniline water gentian violet for 1 to 3 minutes, treatment with Lugol's solution (iodine 1 part, potassium iodide 2 parts, water 300 parts) for 1 to 3 minutes, decolorisation in absolute alcohol and counterstaining with Bismarck brown or safranin.

It has been the experience of many bacteriologists that this original method is replete with possibilities of error, and demands constant super-

[1] Fortschritte der Medicin, 1884, 2, 185.

vision of the reagents and a carefully regulated technique. It will be serviceable to call attention to these possibilities of error.

(1) *Thickness of Film.*—If the film be thick or irregular in its thickness, decolorisation becomes difficult, and Gram-negative organisms may in parts retain the stain.

(2) *Drying Over the Flame.*—If this be accomplished too rapidly, and the film be subjected to too great a heat, ambiguous results are obtained.

(3) *Aniline Water Gentian Violet.*—This has to be fresh: old solutions fail to afford a differential stain.

(4) *Iodine Solution* (Lugol's Solution).—To a slighter extent the same is true regarding this. With age and exposure it loses its differential properties.

(5) *Alcohol.*—This *must* be absolute, *i.e.*, 98 per cent. or over. Weak alcohol decolorises Gram-positive organisms. There is gradual decolorisation with absolute alcohol, but only after a length of treatment that is not employed in ordinary routine. It should never be used for more than two minutes.

(6) *Counter-stain.*—Gram-positive organisms, which successfully resist exposure to absolute alcohol for two minutes may be decolorised, the gentian violet being masked (*a*) if the counterstain be in too concentrated a solution, (*b*) if it be made up in a weak alcoholic solution, or (*c*) if when properly prepared its action be prolonged. As a result Gram-positive organisms may appear to be Gram-negative.

To obviate these fallacies numerous modifications have been proposed (Weigert, Unna, Gunther, Nicolle). The most unsatisfactory step in the process is the employment of the unstable aniline water gentian violet combination. This has been replaced by carbolic acid gentian violet. Recently W. Jensen[1], of Copenhagen, has shown that the intensifying action of ether aniline-water or carbolic acid on gentian-violet is quite unnecessary,[2] and as his method removes the greatest stumbling-block in the way of successful technique, and gives excellent and consistent results, the Committee recommend that it be employed to the exclusion of the original method. Briefly, Jensen (1) discards the aniline water, (2) increases the concentration of the iodine solution, and (3) counterstains by neutral red.

The exact technique of Jensen's method may be described as follows:—

1. Make the film thin and evenly distributed.
2. Fix in the flame, taking care to avoid overheating.
   (In laboratories dealing with much routine examination, it is to-day almost universal to make films on the slide and not on the cover glass. Overheating is guarded against by testing the heated slide against the back of the hand.)
3. *Let the preparation become cool.*
4. Stain with a 0·5 per cent. aqueous solution of methyl violet (6 B)[3] for one minute to half a minute.
5. Pour off the mass of methyl violet solution and wash away the remainder with a drop or two of strong Lugol's solution (iodine 1 part, potassium iodide 2 parts, distilled water 100 parts). Do not wash off with water.

[1] *Centralbl. f. Bakt.*, I. Abt. Orig., 1913, 49, 1683.

[2] Jensen considers that the essence of the process lies in the reaction between the dye and the tissue-proteins (Gram's iodine-methyl violet and Weigert's iron) and not in the presence of the bacterial body.

[3] The writer has also used Bismarck brown.

6. Pour on a fresh quantity of strong Lugol's solution and leave for one half to one minute.
7. Wash off the iodine solution with *absolute* alcohol (not with water).
8. Pour on fresh absolute alcohol (98 per cent.) moving the slide from side to side as in developing a photographic film. A third quantum of absolute alcohol may be required to complete the decolorisation.
9. Rapidly rinse with a few drops of absolute alcohol followed immediately, without any intervening washing in water, by a solution of neutral red [1]. Let this act for fifteen seconds to one minute.
10. Wash in water; dry with blotting paper and in air, and mount in the usual way.

To test the individual technique it is recommended that there be kept at hand pure cultures of a known Gram-positive organism, such as the *Micrococcus* (*Staphylococcus*) *aureus*, and of a Gram-negative organism (e.g., *B. coli*) and that parallel films of the two be made and stained side by side with the material under examination.

On the limitations of Gram's method in relationship to the diagnosis of gonorrhœa.

It deserves note —

(*a*) That Gram-positive organisms when taken up and digested by leucocytes may lose their Gram-positive character.

(*b*) That more than one observer has noted, in cases of chronic gonorrhœa in which the material is such that a satisfactory film is difficult to obtain, that organisms determined by culture to be gonococci retain the violet stain with unusual obstinacy and appear thus to be Gram-positive.

(*c*) That the stain as such does not distinguish between gonococci and other Gram-negative, but non-pathogenic diplococci which may be present in both male and female genito-urinary tracts.

The Committee are of opinion that these limitations do not seriously affect the diagnosis of the one order of cases in which, in their view, diagnosis by microscopical examination alone gives consistent results, namely the active acute cases of the disease; and that with the figures provided in Plate I. the danger of confusion with other actual or apparent Gram-negative organisms is reduced to a minimum.

III. The Cultivation of the Gonococcus.

Since the gonococcus was first successfully cultivated by Bumm in 1885 many different media have been devised for the culture of this micro-organism. The numbers and diversity of the media employed appear to be an index of the difficulty of cultivating the organism and the dissatisfaction which the various authors have felt

[1] Make up the solution in the proportions of

Neutral red	1 gm.
Distilled water	1,000 ccm.
5 % glacial acetic acid	2 ccm.

If this be found too weak a somewhat stronger solution of neutral red may be employed.

with the media devised by others. Possibly this dissatisfaction may be due to the fact of different strains of gonococci varying in their adaptability to an existence on artificial media. More probably it is due to the omission from the various authors' descriptions of details of preparation which are apparently unimportant, with the result that the copies have been less successful than the originals. As an example, the influence of over-heating the medium designed for the growth of the gonococcus seems rarely to have been mentioned, though it has proved to be a factor of considerable importance, an overheated medium producing a growth which is considerably feebler than one which has been sterilised with the minimum of heat.

The various media which have been devised for the growth of the gonococcus may be divided into three categories:

(*a*) Those which contain human blood, blood-serum, or serous exudates, such as ascitic, pleuritic, or hydrocele fluid.

(*b*) Those containing animal blood-serum.

(*c*) Those which contain none of these but, in their place, artificially prepared enriching substances.

Media which contain human blood serum undoubtedly give the best results, and serum derived from shed blood is better than that of exudates, the latter being apt to vary in their constitution and prove disappointing. Animal serum is often good, that of horse, pig, rabbit and guinea-pig being perhaps the most successful, but the bactericidal action of sera derived from the same species of animal varies, and this has been found by some workers to be a cause of variability in the media prepared from them. Of the artificially prepared enriching substances, many have recently been prepared which have proved very successful in the isolation and subculture of the gonococcus. It is true that the growth obtained on them may not be so good as some which may occasionally be obtained on media of class (*b*) above, but they are not so inconstant as these and are therefore preferable for routine work.

In consequence of the diversity of opinions as to the best culture medium, a series of comparative tests has been carried out by Captain David Thomson, R.A.M.C., at the Rochester Row Military Hospital, and his results have been communicated to the Committee. Three media proved themselves eminently satisfactory: (i) Thomson's human plasma-glucose agar, (ii) Cole's tryptic blood agar, and (iii) Gordon and Hope's trypsinised pea extract agar, each of these having been prepared by its originator. The last named was prepared for the cultivation of the meningococcus, and it is quite probable that if the reaction of the medium were made + 0·6 (Levy's scale) instead of + 1, it would enhance its value as a medium for gonococcus.

The method of preparing each of these is given in Appendix I.

IV. Methods for the Production of a Focal Gonococcal Reaction

Long years before the gonococcus was discovered a common method of testing whether pus had been effectively sterilised was by observing whether abscess or ventral subsidence brought about a return of the gout. Since the causative agent has been known it has been found that the gonococci reappear in the discharge which is so induced. The renewal of the inflammation and discharge is most directly and most effectually

brought about by adopting the principle which Koch introduced with tuberculin. If, that is, there be a focus in which the gonococci are still present, by inoculating or vaccinating the individual with a suitable dose of a suspension of dead gonococci[2] a focal reaction may be set up which is frequently accompanied by an active diffusion of the gonococci. In cases of metastatic gonococcal infection the reaction is manifested by increased pain in, or tenderness of, the affected part. In either case it may be accompanied by a definite rise of temperature with or without malaise.

This procedure is to be adopted with caution, there is danger, for instance, that, if present, a latent otitis or latent salpingitis may be lighted up, with serious results.

An alternative and perhaps less desirable method of inducing active discharge in cases of doubtful urethritis is the introduction of a 0·5 per cent. solution of silver nitrate into the urethra.

V.—The Complement Fixation Test

It is clear from the foregoing statement of procedure that the conscientious examination of a case of suspected chronic gonorrhœa may develop into a lengthy process, demanding repeated appearance of the patient for examination, and, what is more, examination by trained specialists.

Its obvious difficulties suggest the desirability of some test which will more simply indicate the presence of the gonococcus in chronic disease and in this connection it is necessary to discuss the complement fixation test.

During the last seven years a technique has been developed and tested which to a certain extent fulfils the needs of the case, a test which is on similar principles to those of the Wassermann test. Like the Wassermann test its technique is delicate and precise and to ensure satisfactory results it must be performed by those with adequate training in serological methods. Its value is so much appreciated in the United States that at one large hospital at least it is now the practice to test each blood sample obtained both for syphilis and for gonorrhœa by the complement fixation method.

As it is little employed in Great Britain the exact data as to its development need to be set down.

Müller and Oppenheim[1] in Austria were the first to publish on this subject in 1906. They studied a case of gonococcal arthritis and employed as antigen a suspension of a culture of gonococci in salt solution. Bruck[2] reported favourably on the reaction the same year. In 1907 Meltzer[3] of Montreal, working at Johns Hopkins Hospital, reported a series of cases of arthritis tested by this method. The findings of these and other earlier workers were somewhat contradictory, some cases affording positive results, others, with a yet more definite history of gonorrhœal infection and progressive gonorrhœal disease, gave negative findings. The failure of these earlier workers to establish a satisfactory

[2] A sensitive dose is usually 0·1 to 0·05 millions of an emulsion of 100 millions of gonococci per c.c. (1000 by Opie). The exact dose for any doubly positive case must be determined by a tentative test with a small dose.

[1] Münchener medizinische Wochenschrift, 1906, 53, 2361.

[2] Deutsche medizinische Wochenschrift, 1906, 32, 1361.

[3] Meltzer, John Mason, Trans. Amer. Assoc. Phys., 1907, 22, 18; also Meltzer, Samuel J., Gonorrhœa in Women, 1908, 44.

technique was shown by Teague and Torrey[1], whose work was confirmed and extended by Wollstein[2] and Watabiki[3], to be due to the fact that there exist numerous strains of gonococci, which are so distinct that cultures obtained from one case and employed as antigen in the complement fixation test upon another clinically well-defined case of the disease, may yield a negative result. Torrey recognised as many as 14 different strains of gonococcus.

To guard against this defect Schwartz and McNeil[4] (1911) introduced and employed a polyvalent antigen, formed by pooling together several cultures known to be serologically distinct. They found that an antigen composed of six pooled strains failed to detect cases of clinically determined gonorrhœa which were detected by an antigen composed of twelve. To-day there is upon the market, provided by a well known American firm, an antigen containing all the 14 strains described and isolated by Torrey. The multiplicity of strains required to produce an efficient gonococcus antigen is a matter which demands further study.

Here it should be added that blood serum from one other disease only has thus far been recorded as occasionally affording a positive result when tested with gonococcus antigen, namely, cerebrospinal meningitis[5], and here the observations are conflicting. The symptoms of the two diseases are so distinct that if there be this cross fixation it introduces no danger of false diagnosis.

It is this test, as modified by the employment of a polyvalent antigen, that has been extensively employed in the United States, so that there is a considerable literature upon the subject, and on the whole a striking uniformity in the results obtained. Confirmatory reports have been published by Major (now Brevet Colonel) Harrison[6] in this country, and by Owen[7] in Canada.

The Advantages, Disadvantages and Limitations of the Complement Fixation Test.

The obvious advantages of this indirect method of diagnosis are that:

i. It requires no preparatory directions to the patient or action on his part.

ii. It may replace examination of the genito-urinary passages by removal of blood from one of the extremities, and may thus be conducted without a knowledge on the part of the examinee as to the nature of the investigation.

(1) Teague and Torrey, *J. Med. Research*, Bost., 1907. **17**, 225. See also Torrey, *ibid*, 1910, **22**, 95.

(2) Wollstein, *J. Exper. Med.*, N.Y., 1907. **9**, 388.

(3) Watabiki, *J. Infect. Dis.*, Chicago, 1910. **7**, 159.

(4) Schwartz and McNeil, *Am. J. M. Sc.*, Phila., 1911. **141**, 693 and 1912. **144**, 8; and Schwartz, *ibid*, 1912. **144**, 369.

(5) Wollstein (1907) obtained crossed fixation between gonococcus antigen and antimeningococcus serum and *vice versa*. Vanzetti (1907) obtained same. Schwartz and McNeil obtained positive results with Ehrlich's anti-meningococcus serum but none with sera from cases of cerebrospinal fever. Major Bowman, C.A.M.C., reports to this Committee that at Fiskestown in the late epidemic the serum of two cases of cerebrospinal fever was found negative when tested against gonococcus antigen. It is in fact generally admitted that anti-bodies should appear in the blood after acute disease of but a few days' duration, and quite likely that they should make their appearance after repeated [illegible] are necessary for the production of an anti-meningococcus serum. Admitting the [illegible] and the meningococcus are closely related, [illegible]

(6) Harrison, *J. Am. Med. Assoc.*, Lond., 1914. **22**, 125.

(7) Owen, *Canadian Med. Ass. J.*, 1914. N.S. **4**, 1064.

iii. It demands the co-operation of no specialist beyond the pathologist.

iv. Where a positive result is obtained the time consumed in arriving at a diagnosis is very much less than that demanded by the method of direct culture.

The disadvantages hitherto reported are that :—

i. *At very frequently fails in acute gonorrhœa.* Antibodies do not accumulate in the blood in sufficient amount to bring about a positive reaction until the disease has progressed for some three or four weeks.[1]

ii. Even where the disease has become chronic, negative results are obtained in those cases in which the disease has remained narrowly localised. Infection limited to the anterior urethra and *even* particularly in the male gives no positive results; in the female it is generally accepted that the reaction does not show itself when the disease is confined to the urethra or vagina, but only when the cervix uteri has become involved, and the disease has ascended to the level of the uterus, and this in cases in which the gonococci can be demonstrated bacteriologically.

iii. Where gonococcal vaccines are employed as a method of cure the complement fixation test is inadmissible. Of late, active treatment by injection of vaccines has become increasingly common.

iv. The blood serum of patients who have been treated with vaccines may continue to give the reaction for four months. Animal experiments indicate that once antibodies are developed in amounts sufficient to affect the reaction they continue to be produced for some weeks after the gonococci have disappeared from the system. Thus Torrey *[illegible]* found that when the process of immunization of animals against the gonococcus is suspended no change in the complement fixation test is noticeable for ten days; at the end of this period the antibodies in the blood begin to be eliminated rapidly, though they persist for some weeks afterwards. It follows from these observations that positive reactions are obtainable for some weeks after complete cure. From a public health point of view it is open to question how far this is to be regarded as telling against the method, how far as a distinct advantage as a safeguard.

v. It may give non-specific results. Uhle and Mackenzie[2] had the sera of 141 individuals tested by each of four competent serologists. Of these 141, fifteen were what they regarded as normal controls, believed never to have been infected with gonococcus. Only one of the four laboratories reported all the fifteen as negative, two of the laboratories reported one of the fifteen as positive, the fourth found two of them positive. Similar discrepancies occurred with the 17 sera of patients suffering from other diseases who denied having had gonorrhœa. One observer found all these negative, another observer reported as many as five (13·5 per cent.) with positive complement fixation test. But these observations are weakened in the fact that the authors merely state that the observers were competent without giving any indication of the extent of their experience, nor are we advised regarding the technique employed in each of the four laboratories, or as to the sanity of the laboratories. Admittedly even competent serologists need considerable experience with the method before consistent results are obtained. The observations may thus be on a par with the known discrepancies which occur in connection with the Wassermann test when in the hands of those without extensive training and experience in the performance of that test. Workers in the best American laboratories who

(1) Torrey and Hay, *Journ. Am. Med. Assoc.*, Chicago, 1914, 13, 141) state that in no instance was complement fixation found to obtain positive results within six weeks.

(2) *J. Cut. Dis.*, 1913, 102 *et seq.*

are careful to describe their technique, agree with singular accord in laying down that a positive complement fixation reaction is most reliable, more specific in fact than is a positive Wassermann test. It is asserted that, contrary to what is the case in syphilis, there is no non-gonococcal infection in which the blood serum gives a positive reaction. Reference has already been made (on p. 11) to the case of cerebrospinal fever with its allied micro-organism. The observations of Thomas, Ivy & Beardsall[6] that out of 180 cases of possible gonorrhœa, 5 gave a positive reaction with an antigen formed of 3 strains of *Micrococcus catarrhalis* has no direct bearing.[7] What is necessary, and to our knowledge has not yet been afforded, is the demonstration whether or no infections with the *Micrococcus catarrhalis* afford positive reactions with gonococcus antigens.

It will be seen from the above that while it cannot replace other methods of diagnosis, the complement fixation test may, in certain cases, be the only laboratory means by which a gonococcal infection may be diagnosed. It is most likely to be of value in cases of metastatic infection where direct demonstration of the gonococcus may be difficult, if not impossible, and it is in these that the highest proportion of positive results is obtained.

As for the Wassermann reaction, and for the same reasons, the Committee cannot at present recommend any one standard method of complement fixation. They can at most append the methods of four careful observers, each of which has been well tested, and invite workers in this country to report their results with one or other method and suggest improvements.

They recommend that such steps be taken as are necessary to secure the provision of an official standardised polyvalent antigen. It would be an advantage if in addition the polyvalent gonorrhœal antigen supplied by one or other firm were issued under Government control, *i.e.*, that each batch of such antigen be tested officially and issued with date of preparation, serial number, and certificate that it has passed the official test.

They recommend that in tests made for official returns the method of complement fixation employed be clearly stated.

They are of opinion that the laboratories at which gonorrhœal complement fixation tests are performed for the public services should be few rather than many, the laboratories selected for the performance of Wassermann tests being utilised for this purpose.

The fact that the complement fixation test for gonorrhœa has not, so far, with rare exceptions, been employed in Great Britain, makes it possible to recommend that reports upon this test be accepted only from pathologists who have been thoroughly trained in the performance of the test and of the control observations which are necessary for it. In respect to payments for this test, it should be placed upon the same footing as the Wassermann reaction.

(6) *Journ. Inf. Med.* Chicago, 1915, 15, 26.

(7) In both any of these five the same serum gave a stronger positive reaction with polyvalent gonococcus antigen the reaction was to this with the polyvalent gonococcus antigen. See also the same authors in Surgery, Gynecology and Obstetrics, 1914, 19, 281.

VI.—The Keeping of Records.

For statistical and experimental purposes it is important that each venereal clinic should keep a card index or other accurate record of all cases of gonorrhœa presenting themselves for diagnosis. Each card or form should afford the following data:—

Particulars of Case of Suspected Gonorrhœa.

Date of first visit ..... Date .....

Age ..... Sex ..... Name of clinic .....

Character of onset .....

Number of previous attacks .....

Probability of present attack being a relapse .....

Length of time disease has existed .....

Complications { Local .....
Metastatic .....

Nature of treatment previously given .....

Nature of any co-existing venereal disease .....

Diagnosis now made, *positive or negative* (*details, using last appendix*) .....

Methods of diagnosis employed, as below (*underline which*):—

Clinical signs and symptoms only.

Detection of gonococci in secretion from tissue which part(s) ..... { *obtained from* ..... / " *After preparation by injection of vaccine* ..... / *after local treatment* ..... }

Complement fixation.

Co-existence of other micro-organisms .....

Nature of treatment employed .....

Final result .....

Nature of tests employed to ascertain the final result (*Insert in following form*):—

Each laboratory performing tests for venereal disease should forward to the proper authority a return of the results obtained at least once a quarter. In the opinion of the Committee, this would allow a ready supervision of the laboratory results and of the accuracy of laboratory routine, at periods not too far apart to permit serious defects to remain long unnoticed.

It is recommended that such returns, for cases of gonorrhœa, actual or suspected, should be made on the following form :—

LABORATORY REPORT ON EXAMINATIONS FOR GONOCOCCAL INFECTIONS.

Quarter ending.....

A. **Microscopical Examination of Stained Specimens.**

Source of Specimens.	Total Number of Examinations.	No. which contained Gonococci only.	No. which contained Gonococci and also other Micro-organisms.	No. which contained no Gonococci but other Micro-organisms.	No. which contained no Micro-organisms at all.
Male Urethra					
Female Urethra					
Cervix Uteri					
Bartholin's Glands					
Other parts as under :					

B. **Cultures.** Medium usually employed.....

Male Urethra					
Female Urethra					
Cervix Uteri					
Bartholin's Glands					
Other parts as under :					

C. **Complement Fixation Tests.** Method employed.....

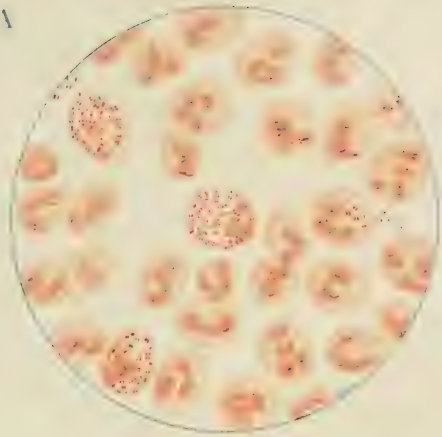
Nature of Affection.	Total Number tested.	Number Positive.	Number Negative.	Remarks.

C.—COMPLEMENT FIXATION TESTS—cont.

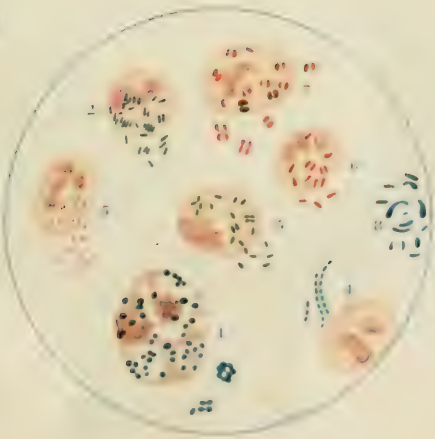
Nature of Affection	Total Number Tested		Number Positive		Number Negative		Remarks
	Males	Females	Males	Females	Males	Females	
Gonorrhœa (confirmed by complement fixation)							
Chancroid							
Puerperal Abscess							
Chronic Pneumonia							
Eye Diseases							
Ophthalmia							
Salpingitis							
Peritonitis							
Arthritis							
Tube Stricture							
Bursitis							
Ileitis							
Endocarditis							
Other Miscellaneous Cases (specify Diagnosis in each case)							
Non-Venereal Affections (specify in each case)							

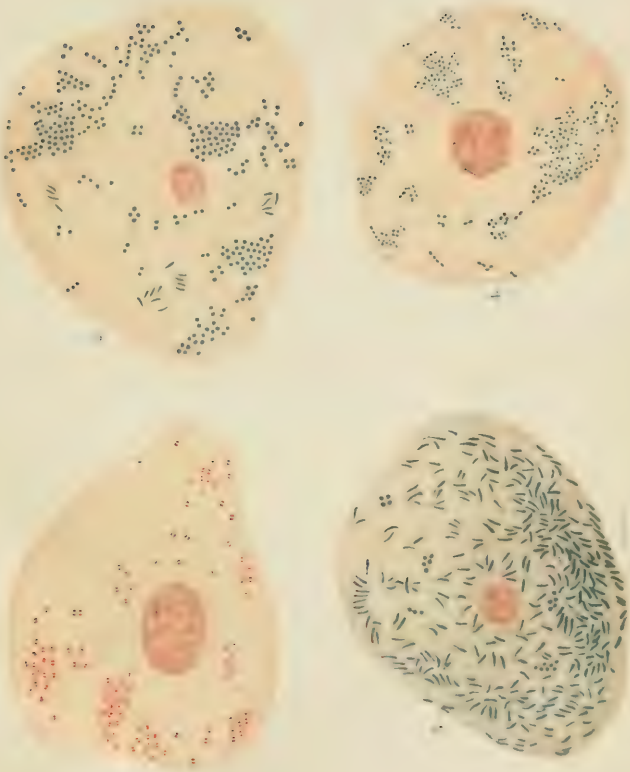
NOTE.—In the report on complement fixation tests for gonococcic and meningococcic arthritis and other conditions, it is desirable to record the number of cases in which the presence of the gonococcus (or other organism) has been demonstrated by other means than the blood serum.

A



B





EXPLANATION OF PLATES I and II

All represent drawings from gonorrhoeal urethral smears, stained by Gram's method (Jensen's modification). Magnification, about 1,000 diameters.

Plate I.

A. Shows pus cells containing intracellular gonococci, also some lying extracellularly. Note that they are Gram-negative and kidney shaped.

B. This is a composite painting made up from various urethral smears to show the different varieties of secondary organisms which frequently occur in gonorrhoeal pus, more especially in chronic cases. All these secondary organisms may occur within pus and epithelial cells, but more commonly they lie extracellularly. Nos. 1 to 6 are painted from the actual specimens. Nos. 7 and 8 are somewhat diagrammatic. Nos. 1, 2, 3 and 5 are the most common types found.

1. Pus cell showing *Staphylococcus albus*. Gram-positive. Note that some are lying partially digested in vacuoles and have lost their gram-positive character.

2. Pus cell showing a diphtheroid bacillus (Xerosis type). Gram-positive.

3. Pus cell showing a short Gram-positive *Diplobacillus* with pointed ends, indistinguishable morphologically from the *Pneumococcus*.

4. Shows a similar organism to No. 3, except that it occurs in chains, resembling a *Streptococcus*.

5. Shows a small *Diplobacillus*. Gram-negative. It assumes various shapes and involution forms, the latter are not kidney-shaped but fanceolate.

6. Pus cell with a large Gram-negative bacillus.

7. Shows the *Diplococcus mucosus* of Rosenthal (?) or "*Pseudogonococcus*." It is weakly Gram-negative, and is four times as large as the *Gonococcus*. It occurs rarely in the urethra, more commonly in conjunctivitis.

8. Shows a diphtheroid bacillus with clubbing and involution forms—Gram-positive.

Plate II.

1. Shows an epithelial cell containing numerous *Gonococci*.

2. Shows an epithelial cell containing many *Staphylococci* and a few diphtheroid bacilli (Xerosis type).

3. Shows an epithelial cell containing diphtheroid bacilli (Xerosis type) and a few *Staphylococci*.

4. Shows an epithelial cell containing numerous Gram-positive *Diplobacilli* resembling *Pneumococci*.

APPENDIX I

THE PREPARATION OF MEDIA FOR GROWTH OF THE GONOCOCCUS

The Committee are indebted to the authors of the media referred to in the text, namely to Captain David Thomson R.A.M.C. to Lieut.-Colonel M. H. Gordon C.M.G. R.A.M.C. and Major I. G. M. Hine R.A.M.C. and to Mr Sydney W. Cole M.A. for the following detailed descriptions of the methods of preparation of their media :—

1. Human Plasma Glucose-Agar (Thomson).

One of the most important points in the preparation of this medium is avoidance of prolonged heating in any of the stages where heating is necessary.

A.—Preparation of Double-strength Meat Extract.

Take a bullock's heart and cut away all the fat. Cut the heart into small cubes and mince them. Weigh the mince and place it in a pan with as many c.c. distilled water as there are grammes of heart. (2) Heat the mixture gently, stirring meanwhile with a glass rod until a temperature of 60° C. is reached. Keep at this temperature for 20 minutes. (3) Raise to boiling point and keep boiling for 10 minutes. (4) Strain through a perforated enamelled iron strainer and four thicknesses of butter muslin. (See Fig. 1).

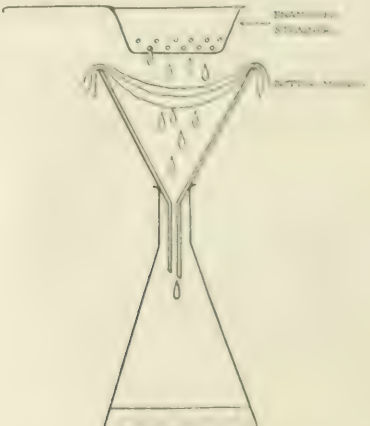


Fig. 1. Straining of Meat Extract.

B.—Preparation of Disodium Hydrogen Phosphate Solution.

Dissolve 10·00 grammes disodium hydrogen phosphate (Na_2HPO_4) in one litre of sterile distilled water.

C.—Preparation of Nutrient Disodium Hydrogen Phosphate Bouillon.

(1) Measure the double-strength meat extract into a sterile flask and add to it an equal volume of the disodium hydrogen phosphate solution.

(2) Weigh out as much good commercial peptone as will make a 1 per cent. solution when mixed with the whole of the extract prepared as under (1). Take about a quarter of this extract, heat it to 60° C. and, in a mortar, mix it with the peptone so as to make a smooth paste.

(3) Add this emulsion to the extract in the flask and steam in the Koch steamer for 45 minutes, in order to complete the solution and stabilise its acidity.

B.—Preparation of Nutrient Agar from the above.

Weigh out sufficient agar-agar to make with the amount of nutrient bouillon prepared as above a 3 per cent. jelly. Mix this into a smooth paste with about one-third of the product at C. 3), which must be cold. Add the mixture to the remainder of the nutrient bouillon in the flask and steam in the Koch steamer until the agar is dissolved. This should occupy not more than 60 minutes in the case of powdered, and 90 minutes in the case of shredded, agar.

(2) Allow the agar to cool to 60° C., whip the white of one egg for every 300 c.c. of the agar solution, and add the froth to the latter. Replace in the steamer and steam for 30 minutes.

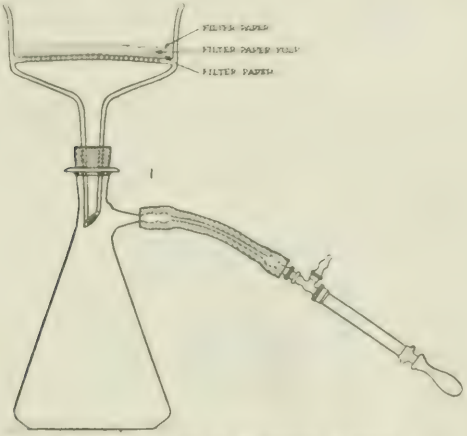


FIG. 2.—METHOD OF FILTERING MEDIUM.

(3) Filter in the steamer through a layer of cotton wool laid in a funnel, or outside the steamer through paper pulp laid on a Buchner funnel fitted into a suction flask (as shown in Fig. 2). Filtration should be as rapid as possible, as the medium deteriorates if it is kept long in the steamer.

(4) Titrate carefully, using phenolphthalein as the indicator, and make the final product 1·6 (Eyre's scale).

(5) Add to the agar solution sufficient glucose powder to make it a 2·5 per cent. solution of glucose.

(6) Replace in the steamer and steam for 20 minutes. It is better to attempt sterilization with one steaming than to steam on three successive days, and with care even the simpler technique of the preceding steps, this is usually successful.

(7) Tube the agar in sterile test tubes, placing about 4 c.c. in each. Store the tubes of agar in the incubator.

E.—Addition of Human Plasma.

Provide the following:—

Apparatus for the drawing off of blood from a vein (see article on tubes).

Sterile 10 c.c. centrifuge tubes, each containing 2 c.c. of a sterile 2 per cent. solution of sodium citrate and plugged with cotton pads.

Cool at colour temperature and allow to stand for 10 minutes with occasional shaking.

Finally add 10 c.c. pyridine.

Prepare any number of tubes (8 about 21 c.c. of boiling water in a suitable test tube and add 10 c.c. of the solution prepared as above. Cork the tubes with corks (one of the tubes previously fitted with a thermometer) and agitate the contents until the corks are separated. Melt the required number of agar tubes prepared as directed above and reduce their temperature to 45° C. Pipette off the supernatant chloroform in the centrifuge tubes and add 0·6 c.c. (1 drop) to each of the agar tubes. Mix the agar and plasma by rolling the tube between the hands, and pour on the usual medium. As a rule the yield from each centrifuge tube is sufficient for a plate (or agar tube) for 20 flasks.

Incubate for 24 hours to make sure the medium is sterile.

II.—Tryptamine Media (Cole.)

To facilitate and improve the preparation of these media the descriptions given below deviate in some details from those adopted in two previous reports to the Medical Research Committee (1)

A.—Tryptamine Blood Extract Agar (T.B.E. Agar.)

(i) *The Plasmatic Extract.* The thought extract previously recommended is now considered to be unnecessary, as the necessity of shaking the plasma with the tryptone in the solution is sufficient to obtain by the method described below.

Fresh pig's peritoneum is found from 24 hours as possible, spread freely on a board and weighed. For every gram of the peritoneum added 1·5 c.c. of 0·2 per cent. hydrochloric acid (by weight). This can be prepared approximately by adding 13 c.c. of pure concentrated hydrochloric acid (Sp. gr. 1·16) to make 1000 c.c. with distilled water. The mixture is well stirred at intervals for 30 minutes. For every 100 c.c. of the peroxide hydrochloric acid used there is now added 4 c.c. of 5 per cent. pyridine (2). The whole is now placed in a centrifuge and run for 10 minutes in a really powerful machine.

The mixture is well stirred and filtered on a large jelloid filter. In the correct amount of acid has been added the filtrate is perfectly clear. It is shaken with a little xylol and the reaction made less acid by the successive addition of 10 per cent. caustic soda. The optimum reaction for the preservation of trypsin seems to be about Ph 7·8. This can be obtained roughly by taking the filtrate until a portion of about 3 c.c. gives only a faint reddish tinge with a few drops of a 0·02 per cent. alcoholic solution of methyl red. It should be tested in a suspended state in a small dark cupboard.

(ii) *The Digestion of the Organs.* To about 1 kilo of organ (3 organs) 2 vessels (preferably in a large vessel generally add 400 grams of the peritoneum) (vide Lancet, 1920, ii, p. 1000, No. 4). Anything to cut and mincing well to cover up to the peritoneum, the "mincing" of lungs. Transfer to a Winchester quart, which has the grease (not) roughly removed by means of a label, by means of a funnel with a wide neck. Wash out the mincing vessel and the funnel with a jet of hot water and add the washings to the main bulk. Make the volume up to 2 litres. Shake well to break up any clumps. As the amount of alkali in the capacity is not quite constant it is advisable to test the reaction of small portions of the mixture with neutral red and with phenol phthalein. The optimum reaction for the tryptic digestion of casein is about Ph 7·8 (3), at which neutral red gives a reddish violet colour and phenol phthalein remains colourless. Should either not give a satisfactory colour it is necessary to add 10 per cent. caustic soda or 0·2 per cent. HCl until the desired point is reached. The mixture must be well shaken after each addition of alkali. If the original mixture gives a reddish tinge with phenol phthalein it is not necessary to subject the mixture to the addition of acid.

To the digestion mixture thus prepared add 10 c.c. of the pyridine extract and 10 c.c. of toluol. Shake well and place in the incubator at 37° C. Shake thoroughly and frequently at 37° to 40° C. Settle the digest and decant the clear liquid. Keep this and wash the residue with water. After the digestion is complete (as to this shaking occasionally for 2 days the digest will settle in from 1 to 2 hours) the residue may be rejected if necessary. As the rate of the digestion the mixture is transferred to a Winchester quart, treated with 10 c.c. of toluol and 10 c.c. of pyridine and digested at 37° C. with occasional shaking for 48 hours and decanted. To the filtrate

(1) Lancet, 1920, ii, p. 1000; (2) Biochem. Journ., 1919, xiii, p. 51; (3) Journal Path. and Bacteriol., 1919, xxii, p. 451.

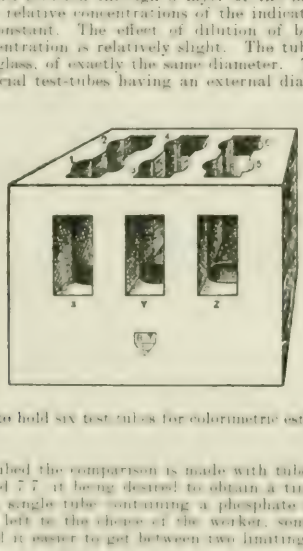
Obtainable from H.M. Stationery Office, Imperial House, Kingsway, London, W.C.2, and 28, Abingdon Street, London, S.W.1; 37, Peter Street, Manchester; 1, St. Andrew's Crescent, Cardiff; 23, Forth Street, Edinburgh, or through any bookseller.

5 per cent. caustic soda is added until the reaction is nearly neutral to litmus, but it is important that it should not be alkaline to this indicator. The fluid thus obtained is known as "stock tryptic broth" or "Tryptamine."(1)

(iii) *Preparation of the Agar.* To 1 volume of the above broth add 2 volumes of tap water, and, if necessary, render the mixture distinctly acid to litmus by the cautious addition of strong hydrochloric acid. Add agar (powdered or fibre) to make 2 per cent. Dissolve by steaming and filter according to the usual laboratory procedure. To every 500 c.c. of the agar at the temperature of 65° to 70° C. add 50 c.c. of defibrinated sheep's blood and one egg-white, well beaten. The addition of the egg-white is found to assist in the subsequent formation of the clot and materially to improve the final yield. The mixture should be transferred to (Erlenmeyer) flasks, and must be steamed for 45 to 60 minutes. The best yield is obtained by steaming in volumes not greater than 1 litre. The bulk of the clot can be very rapidly removed by straining through a fine wire sieve, the clot being squeezed by a glass plate or clock glass. The final clearing is effected by straining through a mat of glass wool supported on a perforated filtering disc in an ordinary funnel, the whole being kept hot by means of a hot water funnel. *On no account must filter paper or cotton wool be employed.*

(iv) *Adjustment of Reaction.*—The reaction is brought to a hydrogen-ion concentration of $P_H = 7{\cdot}6$. The method adopted is that used by Cole and Onslow.(2)

The method is based on the fact that solutions with the same hydrogen-ion concentration give the same tone and intensity of colour with certain special indicators. As bacteriological media are generally coloured, allowance must be made for this by viewing the standard solution through a layer of the medium employed. It is important to keep the relative concentrations of the indicator in the standard and test solutions quite constant. The effect of dilution of bacteriological media on the hydrogen-ion concentration is relatively slight. The tubes used for the method must be of thin clear glass, of exactly the same diameter. The stand figured below is adapted to hold special test-tubes having an external diameter of five-eighths of an inch.(3)



Stand to hold six test tubes for colorimetric estimation.

In the method described the comparison is made with tubes containing phosphate mixtures of P_H 7·5 and 7·7 it being desired to obtain a tint intermediate between these. If preferred a single tube containing a phosphate solution of P_H 7·6 can be employed. This is left to the choice of the worker, some preferring the single tube, whilst others find it easier to get between two limiting tubes.

The standard solutions required are best prepared by adding standard soda to a standard solution of acid potassium phosphate (KH_2PO_4).

0·2 *M Acid Potassium Phosphate.*—Dissolve 27·231 gm. in distilled water and make up to 1 litre.

(1) A concentrated solution of Tryptamine can be obtained from Messrs. Baird & Tatlock, London.

(2) Loc. cit.

(3) The colorimeter stand and special test-tubes can be obtained from Messrs. Baird & Tatlock (London).

0·2 N Sodium Hydroxide.—This can be prepared by diluting accurately standardised normal soda with boiled water in the ratio of thirteen to sixty. To get exact results use only distilled water free from carbonate. This can be obtained by the method given by Clark and Lubs,[1] but for this purpose the ordinary soda gives a sufficient approximation.

Standard Solution P$_H$ 7·0.—To 30 c.c. of the acid potassium phosphate add 47·2 c.c. of the 0·2 N soda and dilute with distilled water to make 200 c.c.

Standard Solution P$_H$ 7·6.—To 50 c.c. of the acid potassium phosphate add 42·8 c.c. of the 0·2 N soda and dilute with distilled water to make 200 c.c.

Standard Solution P$_H$ 7·7.—To 50 c.c. of the acid potassium phosphate add 43·2 c.c. of the 0·2 N soda and dilute with distilled water to make 200 c.c.

Indicator.—0·2 per cent. solution of phenol-sulphone-phthalein ("phenol red"). Dissolve 0·02 gm. in 10 c.c. of 0·02 N soda and dilute with distilled water to 100 c.c. Sterilise by filtration.[2] 10 drops contain 0·2 c.c. of 0·02 per cent. solution, sufficient for 10 c.c. of the nitrate medium required.

Into tube (1) measure 5 c.c. of phosphate solution P$_H$ 7·6 and 0·5 c.c. of phenol red.

Into tube (2) measure 5 c.c. of phosphate solution P$_H$ 7·7 and 0·5 c.c. of phenol red.

To tube (1) add about 5 c.c. of water.

Measure exactly 40 c.c. of the hot agar into 80 c.c. of cold distilled water and mix well. Before it has set measure 10 c.c. into tube (3) and add 1 c.c. of phenol red.

To tubes (2) and (3) add about 5 c.c. of the diluted agar.

Titrate the diluted agar in tube (3) with N/20 soda, preferably from a burette, mixing well by shaking with the thumb and inverting tube a dozen times. If a burette is not available the titration can be done by means of a 1 c.c. pipette graduated in 1/100ths c.c. Continue the addition of the soda until the colour tint seen by looking down the tube to the light and viewing through Y approximates that seen through X. Note the amount of soda used and add half this volume of distilled water to each of the tubes (1) and (2), the purpose being to keep the indicator at the same concentration. Continue to add the N/20 soda to tube (3) until the tint seen through Y is intermediate between those seen through X and Z. Distilled water being added in tubes (1) and (2) as the titration proceeds. It is generally necessary to melt the agar at intervals by immersing the tube (3) in boiling water. It is of the utmost importance that the solution be well cooled before the colour comparison is made as the tint is much affected by temperature variations.

The total amount of N/20 soda required for 10 c.c. of the 1 p. 0 agar is used up. Leave the tube (3) at normal acidity to test later for peptonising organisms, and the whole will serve.

The medium is now ready to be tubed and sterilised. It is probably better to adopt the intermittent method of steaming for 15 minutes on three successive days. For most purposes it can be done by steaming in the autoclave for 5 minutes raising the pressure to 20 lbs. per square inch (1·4 kilogram per square centimetre). Place the contents in a tall cylinder and allow it to stand at room temperature for an hour. Siphon off the clear fluid, which may now be filtered through filter paper. The limpidity of the solution can also be effected by maintaining for two or three hours at 37° C., but no significant loss obtained by this method is met in this case.

The medium must now be neutralised to P$_H$ 7·6. This is done in a manner similar to that described for Medium No. 1 (iv), except that in tubes (2), (3) and the remainder it is of the first importance that no phenol red. This is avoided with N/20 soda from a burette until the tint seen through Y is intermediate between

---

(1) Clark, W. M., and Lubs, H. A., *Journ. Bact.*, 1917, 2, 1.

(2) This and other standard solutions are manufactured by the Cooper Laboratories of Lichfield, Formerly Wulfric.

that seen through X and Z. In this case the volume of water that has to be added to (1) and (5) is the same as the volume of soda employed.

For every 0.1 c.c. of N/20 alkali required for the 5 c.c. of broth, 0.1 c.c. of normal soda is added for 100 c.c. of broth. Sterilise by steaming or autoclaving as described above.

This medium is mainly used for testing fermentation reactions. Glucose, maltose and sucrose are employed in 1 per cent. concentration. The best indicator is phenol-sulphone-phthalein. 4 c.c. of a 0.06 per cent. solution being added to every 100 c.c. of the sugar broth.

C. The Preparation of Tryptamine-Spleen Broth.

Remove the capsule from a bullock's spleen (malt). Mince the pulp and weigh. For every 100 grms. of pulp take 200 c.c. of water and 9 grms. of gelatine. Dissolve the gelatine in the water, cool to 40° C. and add it to the pulp. Incubate for two hours at 37° C. For every 1,000 grms. of spleen pulp taken add 20 c.c. of defibrinated sheep's blood. Add also one egg-white for every 500 c.c. of the total mixture. Steam for an hour. Strain through a fine wire sieve. Cool to 45° C. and measure. To every 100 c.c. add 2 c.c. of one of the pancreatic extracts mentioned above. Place the mixture in a tall cylinder and allow to stand at room temperature over night. Siphon off the clear fluid and measure. To every 100 c.c. add 50 c.c. of tryptamine broth. Adjust the reaction to P_H 7.6 as described for the T.B.E. broth. Tube and sterilise by the intermittent method.

D. The Preparation of Tryptamine-Spleen-Blood Agar.

Prepare tryptamine-blood-extract agar, as described above, except that 2.5 per cent. agar is employed. Adjust the reaction to P_H 7.6, as described in A (iv).

To 200 c.c. of this add 100 c.c. of the tryptamine-spleen-broth also adjusted to P_H 7.6. Tube and sterilise.

III. Lævesinized Pea-Extract Agar ("Lævegar") (Gordon and Hine).

1. *Preparation of Saline Pea Extract.*

Take 100 grammes of peaflour (Pearce Duff's) and add 1 litre of distilled water with 100 grammes of salt. Mix and steam for half an hour, stirring occasionally. Allow to settle and filter, then sterilize and label "Saline Pea Extract." This pea-flour extract should preferably be freshly made for each batch of agar. The filtering should be done through an Egmont make of Chardin's filter paper, which may be obtained from Messrs. Baird & Tatlock's ordinary filter paper or wool must not be used. The quality of the peaflour is of great importance. The extract may be tested by adding one drop of concentrated HNO_3, when a heavy precipitate forms which should dissolve in excess of the acid. The test for starch is not of very much value, the only real test is that of "growth" when the extract is made up with the medium.

B. Preparation of Trypsin Broth (Desiccated).

Take some fresh bullocks' hearts, free from fat and vessels, mince the meat very finely and weigh. To each half kilo add 1 litre of water and make distinctly alkaline to litmus with 40 per cent. KOH solution. Heat in a steamer to 70°–75° C. for two hours. Cool to 37° C. and add 1 per cent. of Lepetit trypsine (or Allen & Hanbury's) and keep it at 37° C. for three hours. (The trypsin preparation mentioned should be used, as several others have not proved satisfactory.) When trypsinising is finished, test for peptone in the following manner:—Take 0.1 c.c. of broth, add 0.1 c.c. of 5 per cent. solution of $CuSO_4$, mix, and then add 5 c.c. of normal NaOH: a true pink colour indicates that trypsinisation is sufficient; a blue-purple shade that it is incomplete. Then render slightly acid to litmus with glacial acetic acid and bring slowly to the boil for a quarter of an hour. Leave covered overnight in a cool place and siphon off the clear liquid in the morning. Make this broth distinctly alkaline to litmus and it is not to be used or stored sterilise in an autoclave at 115° C. for one hour on each of two days. The necessary addition of acids and alkalis must be carefully made little by little, so that there shall be no excess of either.

C. Preparation of Fibre Agar.

Weigh out the required quantity of fibre agar, cut up small with scissors, place in a large flask or enamel pail and wash twice quickly in water. Drain thoroughly, add water just to cover and put in glacial acetic acid to 0.25 per cent. Mix well and leave for a quarter of an hour. Pour off the liquid and wash thoroughly four or five times to make sure that all the acetic acid is washed out. Drain carefully

II. La Media Empleada

Take 5 thousand quantity of the prepared broth and 1.5 per cent agar (the prepared as above and 0.1% gentian violet) dissolve in per litre. Autoclave at 115° C. for three quarters of an hour to dissolve the agar. Titrate about 20 c.c. of the resulting mixture with $\frac{N}{10}$ $NaOH$ after having added phenolphthalein (0.2 per cent. solution) as an indicator adding with a pipette to the mixture in a drop at the moment at a time as a whole tube till the first transient flash of Magenta colour result of the amount used from the burette. Then go on with the titration again adding 0.6 c.c. of 1 per cent phenolphthalein in 95 per cent alcohol to the medium and continue until the first faint pink colour appears: take the reading now. The amount of base now required over the point to obtain the neutral point is determined and the required amount of $\frac{N}{10}$ $NaOH$ solution is then added to the bulk of the medium. This medium should now prove alkaline to phenolphthalein and acid to phenolphthalein. Cool to 60° C. add white of one egg to a litre, mixing as well. Autoclave again at 115° C. for 20 minutes to fix the coagulated egg albumin. Filter again through the Chamberland paper supplied by Baird & Tatlock, and to the filtrate 5 per cent. of the sterile pea extract and distribute in the sterilized way. This medium must be prepared every time necessary, as it gives off ammonia on standing, which alters the reaction if kept too often.

For the cultivation of both the meningococcus and the gonococcus it is advisable to add 2 per cent. (1 c.c. sterile 2 per cent. inactivated solution of rabbit's blood to normal saline, obtained by the addition of 20 per cent. of ether.

APPENDIX II

COMPLEMENT FIXATION TESTS FOR GONORRHŒA

I. Method of Schwartz and McNeil

Given in "The Complement Fixation Test in the Diagnosis of Gonococcic Infections"[1] by H. J. Schwartz, M.D., and Abraham McNeil, M.D. (From the Department of Clinical Pathology of the Cornell University Medical School, New York.) American Journal of Medical Sciences, 1911, N.S. **141**, 693.

---

[1] In our work we have used both the antisheep and antihuman hæmolytic systems and have followed the technique as laid down in the well-known Wassermann test for syphilis, and in Noguchi's modification of the Wassermann test. We might however say that in employing the antihuman system we have invariably used *fresh*[2] patients' serum. The preparation and titration of the antibody, complement, and red blood cell suspension in the two systems has been so frequently described that we do not think it necessary to enter into the details here.

Preparation of the Antigen.—In the preparation of the antigen from the various different strains of gonococci have been used at various times:

1. In cultures of gonococci (type 24) in 48-hours old serum on Thalmann's medium (2) containing 2 per cent. of glucose (2 per cent. of starch, 0.85 per cent. saline solution to each tube was added and the growth at once detached off the surface of the media with a platinum loop.

2. The resulting suspension of cocci in saline was then decanted into a sterile tube and placed in the water-bath at a temperature of 60° C. for 30 minutes, it was then placed in a shaker and agitated for 24 hours, after which it was ready

---

[2] This fixation test can also be performed by any of the media described in the Appendix I (pp. 18–24).

fugated; the supernatant fluid was then pipetted off and placed in a tightly corked sterile bottle, a capillary drop of lysol being added as a preservative. This was placed in the ice chest until required for tests.

Some recent experiences have led us to believe that possibly a better antigen might be obtained by allowing the suspension of cocci in the saline to remain for several hours without shaking, at a temperature of about 37° C., as a more thorough extraction seems to take place by so doing.

For the titration of the antigen we have used as a positive control either the serum of a patient who has been treated with injections of dead gonococci, or else Torrey's antigonococcic serum, as prepared by Parke, Davis & Co. This is serum from an animal which has been immunized against many different strains of gonococci. The quantity of antigen to be used is the quantity that will completely inhibit hæmolysis of the given suspension of red blood cells in the presence of definite quantities of positive serum and complement, provided that double the amount does not interfere with complete hæmolysis of the cells, using a normal serum and complement. Our daily routine is as follows:

1. *Titration of the Complement* with the given quantity of red blood cell suspension and given quantity of an amboceptor of known hæmolytic strength, the object of this being to determine the exact complement value of the guinea-pig serum used. Careful estimation of the exact quantities of cells, opsin and complement to be used is of the greatest importance if accurate and reliable results are to be obtained.

2. *Titration of unit opsin* against a positive serum. This procedure gives us known quantities of amboceptor, complement, antigen, and red blood cell suspension.

The technique of the day may be graphically depicted as follows, using the anti-sheep hæmolytic system in a positive case:

TABLE I

Patient's Serum.	Antigen	Complement 10 per cent.	Amboceptor	Sheep's red blood cells 5 per cent.	Hæmolysis.
0·15 c.c.	0	0·05 c.c.	0·05 c.c.	0·05 c.c.	Complete.
0·10 c.c.	0	0·05 c.c.	0·05 c.c.	0·05 c.c.	Complete.
0·05 c.c.	0	0·05 c.c.	0·05 c.c.	0·05 c.c.	Complete.
0	Double titrated quantity	0·05 c.c.	0·05 c.c.	0·05 c.c.	Complete.
0	0	0·05 c.c.	0·05 c.c.	0·05 c.c.	Complete.
0	0	0	0·05 c.c.	0·05 c.c.	None.
0	0	0·05 c.c.	0	0·05 c.c.	None.
0·15 c.c.	Titrated quantity	0·05 c.c.	0·05 c.c.	0·05 c.c.	None.
0·10 c.c.	"	0·05 c.c.	0·05 c.c.	0·05 c.c.	None.
0·05 c.c.	"	0·05 c.c.	0·05 c.c.	0·05 c.c.	None.
Pos. serum					
0·10 c.c.		0·05 c.c.	0·05 c.c.	0·05 c.c.	None.
0·10 c.c.	0	0·05 c.c.	0·05 c.c.	0·05 c.c.	Complete.

II. Owen's Method.

Abbreviated by permission from the Address by Major J. J. Owen, C.A.M.C., Canadian Medical Association Journal, 1914, N.S. 4, 1074.

The technique is given here in detail because it is careful preparation of the reagents is essential for the best results.

Complement.—A guinea-pig is bled 12 hours before the tests by cutting the carotid arteries. The blood is allowed to clot, put on ice, and immediately before use the serum is withdrawn. It is diluted by normal saline (0·85 per cent.) to [illegible] per cent.

Amboceptor.—Four or six injections of from 2 to 5 c.c. of [illegible] per cent. of fresh sheep red blood cells in normal saline (0·85 per cent.) are made into the ear vein of a rabbit at intervals of five days. Ten days after the last injection the animal is bled to death and the serum separated. If possible the rabbit is not bled, the blood is allowed to clot, the serum subsequently separated by [illegible] at 56° C. for 30 minutes to destroy the natural complement, mixed 1:1 with glycerin and stored in ice.

Red Blood Cells. Fresh sheep blood cells are washed with saline and centrifuged several times until the supernatant fluid is absolutely clear.

Serum as a Source of Complement. Blood is drawn from the vein of the patient directly into test tube and the serum withdrawn. The serum is cleared by centrifugation and is inactivated by heating at 56° C. for 30 minutes in order to destroy the complement present.

Antigen. Cultures of gonococci are grown on hydrocele fluid dextrose agar for 24 hours and washed off with sterile distilled water. The suspension is centrifuged, mixed with sterile distilled water, and the supernatant fluid removed.

This is repeated three or four times to remove extraneous material derived from the media. About 10 cc. of sterile distilled water is then added to each 0.5 gm. of sediment and the suspension warmed in water tubes and placed in water at 56° C. for half an hour. It is kept in a warm place (incubator) for ten days, being shaken for about ten minutes each day on a vortex shaker. It is then centrifugated and the supernatant fluid withdrawn to be used as antigen. A drop of carbolic acid or thiol is added to prevent contamination. To make a gelysated antigen a certain standard technic is used.

Dilutions of the reagents are necessary to establish their titres. Complement has been found to vary frequently and to necessitate titrated before every series of tests. Antiserum also changes on a rare occasion but can be put into test in lower dilutions for several months if stored in refrigerator.

In the present study employed the titres and reactions are made on a basis of a unit quantity of 0.1 c.c. in each tube. In both the quantity of red cells used is 0.2 c.c. of a 2.5 per cent emulsion of fresh red cells in normal saline. In the tests about the appropriate antiserum and of complement necessary in each tube is made up to 1.5 c.c. with saline in each case for convenience in handling the process.

Titration of Complement. Ten per cent complement was added in each of the tubes. The complement value of guinea pig serum has been found to vary considerably especially in young pigs. In the system here employed the unit has been found to vary between 0.3 c.c. and 0.15 c.c. or as 10 per cent. Anything greater than 0.3 c.c. is excessive in the titration. In the titration of complement which is made every day before the tests proper the unit is accomplished as to the proper day in order to be standard. The following is a table of the titration:

Tubes	1.	II.	III.	IV.	V.	VI.	VII.
Antiserum	1 unit in each tube.						
Complement	0.5 c.c.	0.4 c.c.	0.3 c.c.	0.25 c.c.	0.2 c.c.	0.15 c.c.	0.1 c.c.
Red Blood Cells	0.2 c.c. in each tube.						
Saline	Add sufficient to make the total quantity 1.5 c.c. in each tube.						

Incubate in a water bath at 37° C. for three minutes. The best amount of complement and serum employed is to be taken as the unit of measurement.

Titration of Antiserum. With this serum 0.3c.c. has been found most suitable in 10 per cent of complement in saline with 2 units of complement. The best titration of serum therefore is necessary to the establishment of the unit, although the amount of it depends entirely on the strength of the antiserum. The usual titration in the case of an antiserum having to be approximately this strength would be as follows:

Tubes	I.	II.	III.	IV.	V.	VI.	VII.
Antiserum 1-100	0.6 c.c.	0.5 c.c.	0.4 c.c.	0.3 c.c.	0.2 c.c.	0.15 c.c.	0.1 c.c.
Complement	10 per cent in each tube.						
Red Blood Cells	0.2 c.c. in each tube.						
Saline	Add sufficient to make the total quantity 1.5 c.c. in each tube.						

Incubate in a water bath at 37° C. for 60 minutes. The unit of antiserum to be used is the unit as represented by the tube containing the least amount which shows complete inhibition.

Fixation of Antigen. It is necessary to determine the antigenic value of the antigen and also to obtain the presence of anticomplementary properties. In a specific antigen there should be a wide margin between these two. Antianticomplementary properties should not be present in less than twice the amount of antigen used in the tests otherwise there would be the danger of false positive reactions. A 50 per cent solution of antigen in normal saline is usually used in preliminary examination of its antigenic properties, although the best is found

to be too concentrated, in which case a weaker solution is used. The following table gives the usual routine titration:—

Tubes	I.	II.	III.	IV.	V.	VI.	VII	VIII.	IX
Antigen, 20%	0·05 c.c.	0·1 c.c.	0·2 c.c.	0·4 c.c.	0·6 c.c.	0·8 c.c.	1 c.c.	1·2 c.c	1·4 c.c.
Complement 10%	2 units in each tube								
Known Positive Serum	0·2 c.c in each tube.								
Saline	Add to 2 c.c. in each tube								

Incubate in water bath at 37·5° C. for thirty minutes, then add:—

Amboceptor	2 units in each tube.
Red Blood Cells 2·5%	0·5 c.c. in each tube.

The presence of antigenic qualities is determined by the presence of inhibition of haemolysis, and in a good antigen this should be present in the second or third tube.

To determine the anti-complementary properties the above test is repeated, omitting the known positive serum. This is an important titration, and in a suitable antigen haemolysis should be complete in the tube representing double the unit of antigen chosen for the test.

The routine usually followed each day when tests are made is:—

1. Titration of complement.
2. Titration of antigen.
3. Tests proper. Here three tubes are used—one as a control without antigen and the other two with different quantities of antigen. The unit of antigen used is usually one-half the greatest amount showing complete haemolysis in the anticomplementary titration. A known positive and a known negative serum are included in each series of tests as additional controls.

The following is a table of the test:—

Tubes	I.	II	III.
Suspected Serum	0·2 c.c. in each tube.		
Complement	2 units made up to 0·5 c.c. in each tube.		
Antigen	None.	½ unit.	1 unit
Saline	Add to make total quantity 1·5 c.c. in each tube		

Incubate in water bath at 37·5° c.c. for thirty minutes and then add:—

Amboceptor	2 units made up to 0·5 c.c. in each tube.
Red Blood Cells 2·5%	0·5 c.c. in each tube

Return to water bath at 37·5° C. for thirty minutes.

Instead of the last step in the above tabe the red cells may be sensitised synchronously with the first part of the test by adding equal quantities of amboceptor (two units made up to 0·5 c.c. with saline) and red cells. The mixture is incubated in the water bath at 37·5° C. for half an hour. One c.c. is then added to each tube and the tubes returned to the water bath. The sensitising of the red cells has the effect of hastening the reaction.

The method of reading the results is of importance. This is done when haemolysis is complete in the controls. A strong positive reaction consists in complete inhibition of haemolysis. For diagnostic purposes it is doubtful if it is wise to return a report of a positive reaction if there is less than 50 per cent. inhibition of haemolysis which we would term a weak positive reaction.

III.—Kolmer's Method.

Method compiled by John A. Kolmer, M.D., D.P.H., Instructor of Experimental Pathology, University of Pennsylvania, Pathologist to the Philadelphia Hospital for Contagious Diseases, and issued by permission from the "Practical Institute of Bacteriology, Diagnosis and Specific Therapy." Philadelphia and London: W. B. Saunders Company, 1912. pp. 368–369.

"*Hemolytic Complement Amount.*—In order that the complement titration may be employed, the various unphysiological factors must be eliminated. The guinea-pig complement is the original Wassermann complement, and therefore the quantity employed in the original Wassermann method may be employed. I prefer to employ the larger amounts because the results are usually more constant.

Fresh guinea-pig complement, usually 1–20 and used in dose of 1 (= 0·05 cc. serum), 1½ (= 0·075 cc. serum), or 2 (= 0·1 cc. serum) units, is employed. The serum is inactivated and used in dose of 1 unit, antisheep corpuscular amboceptor is titrated and used in an amount equal to 2 hemolytic doses in combining the complete titration and in the test proper.

Kolmer and Bilsky have compared the practical value of the antisheep and antihuman hemolytic systems in the examination of a number of sera. While the latter were said, some of the sera have contained antigens and yielded slightly better results, showing the additional possibility of natural antibody production in a large proportion of human sera.

Antigen.—The antigens for use in complement fixation in the form of Noguchi and Lange and Kolmer and McNeil have been employed. The antigens should be prepared in many different manners as suggested. The difficulty in following any organic and the necessity for employing a concentrating and heating a large number of strains have rendered it practically impossible for most persons to prepare a gonococcus antigen. Therefore, until further methods are devised, one antigen is best prepared in large central laboratories where the cultures are handled and prepared by specially trained persons.

The gonococcus are best grown on a solid agar medium containing no sugar or phenolphthalein. To obtain a rich growth of virile gonococci must first be cultivated. After cultivating for from 24 to 48 hours, the gonococci are washed off with sterile salt solution and the emulsion is heated to a temperature not over from 56° to 60° C. for one hour, allowed to stand in the ice-box for 24 hours at 5° C., and heated again to 56° C. for one hour. The sterility of the antigen may be controlled and proved through a Berkefeld filter which is reserved for this purpose alone and is certain in reaction. A small amount of preservative, as 0·25 per cent. of a 1:100 aqueous solution of phenol to each cubic centimeter of antigen, may be added. The antigen is also well preserved in small amounts as ampoules, that are sealed and heated to 56° C. for half an hour on three successive days. Just before using, heat the antigen a second time by adding one part of it to one part salt solution to save part of antigen. I prepare the antigen in ampoules containing 1 cc., and when preserving the antigen from the ampoule in a large quantity, add 1 cc. of 10 per cent. salt solution, and dilute the whole 1:20 with the addition of 8 cc. of normal salt solution, after which the antigen is ready for use.

In this method of preparing antigen the antibodies contained in the gonococcus protoplasm, which have also been found in the sera of patients suffering from gonococcus infection, are not removed. Kolmer and Bilsky, after an experimental study of the various antigens, found that a stronger complement-fixation is obtained with antigens containing antibodies. The various strains are grown for from 48 to 72 hours, and are then washed off with sterile saline solution, observing particular care not to include portions of the culture medium. The suspension is then shaken to break up clumps, and heated to 56° C. for an hour. A small amount of preservative is then added, and the mixture stored in 2 cc. ampoules. Before using, it is diluted 1:20 to 1:30, and titrated for the anticomplementary dose. Wardin has reported good results with a new liquid antigen.

A number of antigens have very little practical value, as they fail to give satisfactory results in obtaining the antigenic principle of gonococci.

The anticomplementary dose of the antigen should be determined, and another of comparative value should be used in employing the gonococcus. As antigens diminish in value they should be replaced with an antigen of greater activity, to determine the antigenic value of the antigen, one is prepared at a definite time and that

the anticomplementary dose. This *titration should be conducted and the antigen standardized before the main tests are adjusted.*

In the following table the results of an anticomplementary titration of a gonococcus antigen are given, the approximate dose having been ascertained in previous titrations:—

Anticomplementary Titration of a Gonococcus Antigen.

Tube.	Antigen 1:10 c.c.	Complement, 1:20 c.c.	Saline solution to each tube to 2 c.c.; tubes are shaken and incubated for 1 hour at 37° C.	Anti-sheep Amboceptor, 1 Unit.	Sheep's Corpuscles 1·2·5 per cent.	Tubes are shaken and incubated for 1 hour at 37° C.	Result—Hæmolysis
1	0·2	1		2	1		Complete hæmolysis.
2	0·4	1		2	1		Complete hæmolysis.
3	0·6	1		2	1		Complete hæmolysis.
4	0·8	1		2	1		Slight inhibition of hæmolysis.
5	1·0	1		2	1		Marked inhibition of hæmolysis.
6	0	1		2	1		Complete hæmolysis.

If the antigen is new and the anticomplementary dose is entirely unknown, it may be necessary, in making this titration, to use a different dilution, with higher and lower doses. In conducting the main test the foregoing antigen could be used in dose of 0·2 or 0·4 c.c. of this dilution.

The Test.—The serums should be fresh and clear, and heated to 56° C. for one-half hour. For each serum use four test-tubes, 12 by 1 cm., arranged in a row. Into each of the first three place the dose of antigen and increasing doses of serum, 0·05 c.c., 0·1 c.c., 0·2 c.c., the fourth tube is the serum control, and into this is placed the maximum dose of serum, 0·2 c.c., but no antigen. 1 c.c. of complement diluted 1:20 is added to each tube. The following controls are included:—

1. A positive control with an antigen-positive serum or with the serum of a patient who reacted positively on a former occasion.

2. A negative control with the serum of a healthy person.

Both of these controls may be set up with but the maximum dose of serum, 0·2 c.c.

3. The serum control of each serum is contained in the fourth tube of each series. At the completion of the test this tube should show complete hæmolysis and thereby indicate that the serum was not anticomplementary.

4. The antigen control at this time includes the dose of antigen and complement.

5. The last tube contains control at this time to test the dose of complement.

6. The corpuscle control receives 1 c.c. of the corpuscle suspension.

To each tube (except saline control) is added to bring the total volume up to about 2 c.c. The tubes are shaken and incubated for one hour at 37° C. in the thermostat or in a water bath (not less than 1 hour), after 2 units of amboceptor and 1 c.c. of sheep corpuscle suspension are added to each tube except the corpuscle control. The tubes are gently shaken again and incubated for an hour or longer, depending upon the hæmolysis of the controls, after which the results are recorded. The corpuscle suspension may be prepared and the tubes placed in a refrigerator overnight and the results read the next morning. Under these conditions hæmolysis occurs slowly and according to some workers in this field the reaction becomes more delicate. *Conducting the process in addition by passing the tubes in a refrigerator at 8° C. for 4 hours is recommended.* The method of McNeil, followed by the addition of 2 units of amboceptor and 5 c.c. of corpuscle suspension to each tube and incubation in a water bath at 38° C. for 2½ hours, gives particularly delicate readings and removes the danger of spontaneous fixation of complement.

The following table is an example of a quantitative fixation test with the serum of a case of gonococcal arthritis.

Quantitative Complement Fixation Test

Patient's Serum No.	Antigen 1–10 c.c.	Complement (guinea-pig) 1–10 c.c.	Salt solution to make up to 4 c.c. and incubated for 1 hour at 37° C.	Anti-sheep Ambo-ceptor Units	Sheep's Corpuscles 12/0 c.c.	Results after one and a half hours incubation.
1/80	0·2	1		2	1	Slight retention of haemolysis
1/1	0·2	1		2	1	Marked inhibition of haemolysis
1/2	0·2	1		2	1	Complete inhibition of haemolysis
1/4	0	1		2	1	Serum potential haemolysis
Pus Serum.						
1/4	0·2	1		2	1	Complete inhibition of haemolysis.
1/2	0	1		2	1	Serum potent haemolysis.
No. 2 Serum						
1/2	0·2	1		2	1	Haemolysis
1/2	0	1		2	1	Haemolysis
0	0·2	1		2	1	Antigen control for haemolysis
0	0	1		2	1	Haemolytic control for haemolysis
0	0	0		2	1	Corpuscle control for haemolysis

In reading the results the controls are first examined and should show complete haemolysis. The test is reported as negative if all the tubes are completely positive in the largest dose only of serum, 0·2 c.c., showing inhibition of haemolysis, moderately positive if the 0·1 and 0·2 c.c. doses of serum show inhibition of haemolysis and strongly positive if the 0·05, 0·1 and 0·2 c.c. doses react positively.

The test may be conducted with two doses of serum, namely, 0·2 c.c. with the antigen and 0·2 or 0·3 c.c. in the serum control tube after the manner of the original Wassermann reaction. In this case the readings are made after the usual [illegible] method.

Quantitative Complement Fixation Test Using One-tenth the Usual Amount.

This method is employed for purposes of economy, especially since the antigen is likely to be expensive. Otherwise the method is less desirable than the preceding one, as the results are more difficult to read.

Complement titration is different. 1–10 are used in dose of 0·1 c.c. corpuscles are used in 0·1 c.c. 10 per cent. suspension and used in dose of 0·1 c.c., the antiserum is titrated with three amounts of complement and corpuscles and used in dose equal to two units. Each day before the serum tests are undertaken the complementary unit of antigen is determined by placing decreasing doses of titrated antigen with complement and salt solution in a series of tubes incubating for an hour, adding two units of amboceptor and the corpuscles, followed by incubation for another hour. One-half of one-quarter of the antigen-amboceptor dose is used in making the main test. The serums are measured out and to them necessary doses of 0·05 c.c., 0·01 c.c. and 0·02 c.c. equivalent respectively to 0·2 c.c., 0·1 c.c. and 0·2 c.c. of a 1–100 dilution (0·1 c.c. serum, 9·9 c.c. salt solution). The fourth tube of each group contains the maximum dose of serum without antigen, and is the serum control. The other controls, general technique, and readings of the reaction are the same as those previously described.[1]

IV.—Thomson's Method.

A new method of preparing Gonococcus Antigen and a new technique for the Complement Deviation Test.

Captain David Thomson R.A.M.C., M.B., Ch.B. (Edin.), D.P.H. (Camb.), has been good enough to communicate for the purposes of this Report the following preliminary description of some new methods. His work was carried out in the laboratory of the Military Hospital, Rochester Row, London, S.W., under the direction of Colonel L. W. Harrison, D.S.O., K.H.P.

Introduction.—The complement deviation test in gonorrhœa is destined to be of great importance. It is well known that it is extremely difficult to determine by clinical and microscopic methods, when a patient is definitely cured of this disease. This is especially true in the case of women, and it is a great responsibility for a physician to state that a given case is free from infection. The test will come to be of great value in this respect. It will prove a great source of help to the gynæcologist and will aid considerably in the differential diagnosis of many obscure cases of joint disease.

Researches which led to the new method of preparing the Gonococcus vaccine.—The gonococcus is a germ which autolyses or breaks up very readily. For this reason a vaccine of the organism does not keep well, but rapidly disintegrates and eventually becomes an autolysate. An investigation was carried out with a view to finding the cause of this autolysis, so that a more stable vaccine might be prepared. I eventually ascertained that weak acids prevented autolysis, but that weak alkalis increased it. In consequence we now put up the vaccine in a weak acid solution by using 0·6 per cent. acid sodium phosphate instead of ordinary saline. In the course of this research I found that the gonococcus was extremely soluble in alkali, so much so, that if a profuse growth of the germ is shaken up with beads in an $\frac{N}{10}$ or $\frac{N}{20}$ solution of sodium hydrate, a clear solution is formed almost instantaneously. If sufficient acid be added to this alkaline solution to render it acid, a white precipitate is immediately formed, which I take to be a precipitate of fatty acids. So it would appear that the gonococcus consists largely of a fatty substance, which is immediately saponified by the addition of an alkali. The meningococcus is similarly soluble in alkali but apparently not quite so soluble as the gonococcus and a faint milky tint is left in the solution. A strain of micrococcus catarrhalis on the other hand is not soluble in alkali, so that a permanent opaque white emulsion remains after shaking up a growth of this organism in $\frac{N}{20}$ sodium hydrate. It seems to me that this might be a useful method of distinguishing between these three allied species of organisms.

Method of preparing the Gonococcus antigen.—Colonel Harrison asked me to try to work up the complement deviation test for gonorrhœa. He had used the ordinary gonococcus vaccine as antigen with successful results in 1914. In consequence I employed at first our stock vaccine and found that it gave successful results when used in a strength of about 100 millions per c.c. More concentrated vaccine were too anticomplementary for use. It then occurred to me that an antigen prepared by dissolving the gonococci in alkali and then rendering neutral, might be suitable and instead of proceed to be separated as the vaccine itself being less anticomplementary and at the same time more powerful as an antigen in the blood test.

I carry out the following method of technique:

(1) Prepare a standard emulsion of gonococci, such that 1 c.c. contains 1,000 millions per c.c. (one prepared this by a method exactly about 1 c.c. in a separator. (Emulsion in 0·6 per cent. NaH_2PO_4 + 0·5 per cent. carbolic acid.)

(2) Shake up a portion (growth of gonococci 24 hours incubation) in a test tube containing beads and about 6 c.c. of saline.

(3) Add to half of this concentrated emulsion in a test tube A of the same character as that which contains the standard and add the other half to a similar test tube B.

(4) Dilute the emulsion in tube (A) until it exactly matches the standard emulsion (1,000 millions per c.c.).

(5) To the other tube B add a few drops of $\frac{N}{10}$ sodium hydrate or dissolve the gonococci. A clear alkaline solution will be immediately obtained.

Now add $\frac{N}{10}$ hydrochloric acid gradually until it is just neutral to very faintly acidine to litmus. We now have a nearly neutral solution of gonococci. Add to this 0·85 per cent. saline containing 0·6 per cent. carbolic acid until the solution is exactly the same as that in tube (A).

prepared as in (4) to match the antiserum). This gives us a solution containing 1000 antibody of antiserum protein per c.c. This should be correct in the case where all the cells antigen. It appears to keep well and it does not become opaque because of the weak antigen it contains.

(6) To use this antigen dissolve in distilled water (three parts +85 per cent saline to one to bring it to a suitable concentration to 100 antibody per c.c. When used in the Ahlfeldt way, it will be found that this antigen will absorb out a little more than one antiserum homologous and in comparison.

Antigens of many strains of gonococci have been prepared as above and are now being used in this research. So far I have tested the sera of 30 cases with 12 separate antigens as well as with a mixed antigen composed of all the 12 strains together. This has shown clearly that a complement antigen is better than the antigen prepared from a single strain. A single antigen may only give a very weakly positive test with a given serum while the single antigen of a different strain may give a strongly positive test. A compound antigen however gives a good positive where a single antigen may only give a very doubtful positive. It was also considered advisable to use a non-gonococcal antigen simultaneously with the gonococcal antigen in my experiments and a culture of this organism was kindly given by Major Hine, R.A.M.C. So far my experiments have shown that the non-gonococcal antigen almost invariably gives a weakly positive result with a strongly positive gonococcal serum, but a weakly positive serum gives a negative result with the non-gonococcal antigen. This shows that the non-gonococcus is a very closely allied organism.

Parke Davis's compound gonococcus antigen was tested against a compound gonococcus antigen prepared by the new method described above. The latter proved to be superior in two respects. It was less anticomplementary and more powerful antigenically, and sera which gave a weak positive with the Parke Davis antigen gave a strong positive with that prepared by the new method. It would appear therefore that a definite advance in the preparation of the antigen has been achieved.

The new technique employed in carrying out the Wood test. For this new and highly satisfactory technique I am indebted to Lieut.-Colonel Harrison. He advises me at the commencement of my experiments to use a solidified serum, and to allow the Stormach fixation of the complement by placing the tube in the incubator overnight previous to the addition of the sensitised cells, according to the method investigated by Dr. Griffith and Scott. Lieut.-Colonel Bond, Bacteriological Laboratory, as a result of their researches on the Wassermann test (unpublished).

(1) *Preparation of RS serum.* 1.5 c.c. of 10 per cent. inactivated (1 hour at 56° C.) serum in 0.5 per cent. lysol, before diluted.

(2) *Standardisation of the complement.* The complement should be titrated against the stock antigen diluted 1 in 10 with 0.85 per cent. saline as used in the test. To prepare Wassermann tubes add 0.1 c.c. of guinea-pig's serum (complement) diluted as follows:—

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1	1	1	1	1	1	1	1	1	1	1	1
10	20	30	40	50	60	70	80	90	100	110	120

To each add 0.1 c.c. of the diluted antigen (1 in 10). Shake the tubes and place the rack in the incubator for one hour. Then put rack in waterbath at 37° C. for half an hour. Add to each tube 0.1 c.c. of fully sensitised sheep's corpuscles (2 per cent. suspension). Replace rack in waterbath at 37° C. and take the readings after 30 minutes. The lowest dilution of complement which produces haemolysis in the whole fluid is taken as one unit-value haemolytic unit.

(3) [illegible] Four tubes A, B, C and D are required.

(a) To A, B and C add 0.1 c.c. of the inactivated serum diluted 1 in 20.

(b) To D add 0.1 c.c. of the inactivated serum diluted 1 in 5.

(c) To A and complement 0.1 c.c. containing [illegible] haemolytic units.

(d) To B [illegible]

(e) To C [illegible]

(f) To D [illegible]

(g) To A, B and C add 0.1 c.c. compound antigen (diluted 1 in 10). Table D [illegible]

(h) Place the tubes in the incubator over night and next morning add to each [illegible] of 2 per cent. suspension of sensitised corpuscles. Then place the tubes in the water bath at 37° C. and take the readings after

15 minutes. The control tube D should show complete haemolysis. Haemolysis in A, B and C indicates a negative reaction. No haemolysis in A, B and C indicates a strong positive. No haemolysis in C alone indicates a weak positive.

An antigen control containing no serum but an equivalent amount of saline and 2% M.H.D. is necessary, since the antigen absorbs a considerable amount of complement during the long period of fixation in the ice-chest. It is not practicable to use the long fixation method in the process of standardising the complement, since the complement deteriorates from day to day. Known positive and negative sera should always be included in the series, and all the tests rejected in the event of these controls being unsatisfactory.

The results obtained have been very satisfactory, and this is due no doubt to the superiority of the antigen as well as to the superiority of the long method of complement fixation in the incubator. In 25 cases the sera of patients whose gonorrhœal discharge commenced less than one week previously 15 positive reactions were obtained. In 48 cases of gonorrhœa complicated and uncomplicated the reaction was positive 322 times. In addition to this use in 28 sera of clinically cured gonorrhœa cases 18 gave a positive reaction. Six out of 16 cases of syphilis, where gonorrhœa was denied, gave a positive reaction. In these cases there was no appearance of hiding the truth at the denial. In no case was a reaction obtained where gonorrhœa could clearly be excluded except in cerebro-spinal meningitis which gave five positive reactions out of five cases tested.

The test also maintains the presence of the gonococcus long after the disappearance of the gonococci according to the microscope and cultural test. A case which had led to thinking very much, gave a strong positive test and he relapsed shortly afterwards.

I wish to thank Dr. Aldous for his assistance in supplying me with cases and the latter to thank me at the hospital. I am especially indebted to Colonel Harrison, D.S.O. for giving me the facilities of the work since the success obtained has been so largely due to technique which he advised.

References.

Harrison, L. W. (1914). Complement Deviation as the Diagnosis of Gonococcal Infections. *Journ. Roy. Army Med. Corps*, Feb., Vol. 22, No. 2.

Thomson, D. (1918). Remarks on the Cause of Arthritis in the Gonococcus, with special reference to the preparation of Gonococcal vaccine. *Lancet*, Path. and Bact. in the Press.

No. 3. METHODS FOR THE DETECTION OF SPIROCHAETES.

CONTENTS.

PAGE

I. Collection of Material ... 35

II. Demonstration of the Spirochaetes ... 37

1. *Dark Ground Illumination* ... 37

2. *Stained Films* 44

3. *Indian Ink and Congo Red Methods* ... 45

4. *Silver Nitrate Methods* ... 45

III. Soft Chancre and Balanitis 47

Appendix I. *The Resolving Power of the Microscope* ... 47

Appendix II. *The Nomenclature of the Spirochaete of Syphilis* ... 47

The Committee in their first report dealt with the diagnosis of syphilis by means of the Wassermann Test. They have now brought together the conclusions reached as to the most satisfactory methods for the microscopic detection of *Spironema pallidum*. They desire to express their great indebtedness to Mr. J. Edwin Barnard, President of the Royal Microscopical Society, for the service which he has rendered in describing in detail the technique of dark ground illumination. The Committee know of no such authoritative description elsewhere, and they have embodied it in the text of the Report.

Too much emphasis cannot be laid upon the importance of the detection of the *Spironema* as affording the earliest means of diagnosis of syphilis, and this at a period when clinically it is not possible to arrive otherwise at a definite decision. *Treatment undertaken in the early primary stage is relatively simple and assured, and is a matter of weeks; after the infection has become generalised, with development of a positive Wassermann reaction or secondary lesions, it is prolonged, uncertain and a matter of months.* It is bad practice to defer diagnosis and treatment until the typical Hunterian chancre has developed. The duty of the medical man is to suspect the syphilitic nature of every localised lesion upon the organs of generation, however small and atypical, and to remember that a simple papule with tendency to ulcerate may show itself even within a few days after infection with syphilis. *It should be the routine practice to examine every such eruption for spirochaetes*, and if these are not found at first, examination should be repeated on subsequent occasions. The most reliable methods of detection are so simple and expeditious that there is no excuse for neglect to utilise them.

I. Collection of Material.

The methods about to be detailed are specially applicable to superficial lesions. They may also be used for examination of the juices of solid organs.

To obtain good results it is, in the first place, necessary to employ *not the contaminated liquid which has collected on the surface, but fluid freshly expressed from the tissues of the lesion*.

The prospect of success is diminished by any previous local antiseptic treatment of the lesion. If any such treatment has been applied the material is to be obtained from the deepest portion of the lesion, or by puncture, with a syringe, of the neighbouring enlarged gland.

7283. Wt. 11427. 500. 3/18. T. & E. C. 56.

Further, it has to be borne in mind that salvarsan and its substitutes administered intravenously in the proper dose have a very rapid action upon the spirochaetes. Within four hours the majority of those present in a cutaneous lesion may be dead and decaying, and have lost their characteristic wavy curvature. Microscopical diagnosis must therefore be made prior to arsenical treatment.

DIRECTIONS.

(a) *Superficial lesions.*

1. Cleanse the sore or the surface of the lesion of all *debris* with a piece of cotton wool moistened with saline or tap water.
2. Squeeze the sore firmly (preferably this is done by the patient himself) until drops of serum are expressed on the surface; or the sore may be lightly scraped with the edge of a spud or scarifier.
3. If bleeding has been caused by the manipulation or cleaning of the sore it is necessary to wait until it has stopped before collecting the sample, as the presence of blood lessens the chance of finding the spirochaetes.
4. Take up the serum in a pipette (Pasteur) drawn out to a capillary end; it is sufficient merely to place the end of the pipette in the exuded serum, when it will be drawn in by capillary attraction.

(b) *Lesions of the mouth.*

Lesions of the mouth are dealt with on the principles outlined above. It is important to avoid the collection of saliva in the specimen as this may contain spirochaetes which are difficult to distinguish from *Spironema pallidum*. The specimen may be removed from the tonsillar region, after scraping, with the help of a capillary pipette.

(c) *Skin lesions.*

Papules.—The superficial layers of epithelium are removed by scraping with a scarifier, and squeezing or devascularising the papule.

Macules.—These may be examined by the application of a blister about the size of a threepenny-bit, removal of the blister fluid and examination of the serum expressed from the raw area.

(d) *Lymph Glands.*

Fix the gland so that it bulges out the skin. Run a fairly stout hollow needle of about 26 gauge into the centre of the gland from one pole. Inject into the gland about five minims of sterile salt solution (0·85 per cent.) with a hypodermic syringe which fits the needle. Massage the gland, fit the syringe to the needle, and apply suction with the piston. Withdraw the needle with the syringe attached and force the aspirated material (which usually just covers the bottom of the syringe) on to the surface of a slide. Collect into a capillary tube if the specimen has to be sent to a laboratory.

II.—DEMONSTRATION OF THE SPIROCHAETES.

1. *Dark ground illumination.*

Undoubtedly the ideal method for demonstrating the *S. pallidum* is by the dark ground condenser. Plates III., IV., V. illustrate spirochaetes demonstrated in this way, and show the main points by which *S. pallidum* can be distinguished from other spirochaetes.

The method of illuminating microscopic objects known as "dark-ground illumination" is of English origin, but in recent years it has

been reintroduced from Germany, and has become a comparatively common means of observation. It is interesting to note that an immersion paraboloid was designed by Edmunds about 1875, and an example of the appliance is to be found in the collection of historical instruments in the possession of the Royal Microscopical Society. In 1879 J. W. Stephenson described a "Catoptric Immersion Illuminator" (Journal of the Royal Microscopic Society, 1879, p. 37), which is a complete anticipation of the dark-ground illuminator introduced by Reichert, and which embodies the main principles of the modern spherical surface dark-ground illuminators which are erroneously regarded as of purely German origin. It must be admitted that dark-ground illumination has not made such headway as might be expected of it, in view of its undoubted merits and advantages. This is perhaps entirely due to the fact that, at least in medical circles, there has been little effort to master the technique of the subject, simple though it is both in principle and practice. In principle the method consists in rendering a microscopic object self-luminous, so that no preliminary treatment, such as fixing or staining is necessary, any suitable material being examined in the living state. The conditions necessary to achieve self-luminosity are that the structure or organism should have a refractive index differing substantially from that of the medium in which it lies, and that it should be illuminated in such a manner that only the light refracted or reflected by the object can reach the eye of the observer. Under these conditions greater visibility is secured, and the object is seen as a bright image on a dark ground. The appliance used to achieve this result is sometimes referred to as an "ultra-microscope," but this use of the term is inaccurate. The term "ultra-microscopic" should only be applied to those methods which enable objects to be made visible that are beyond the limits of resolution by direct methods of microscopic observation. (See Appendix.) The following are the essential parts of an outfit for dark-ground illumination:

The Microscope.—Any instrument suited to bacteriological work may be utilised, but it should be provided with rack-work or lateral screw for adjusting the sub-stage illuminating apparatus and with centring screws for adjusting the condenser. (Fig. 1.) The mirror

Fig. 1.

should preferably be mounted separately from the sub-stage condenser, so that the light having once been adjusted in relation to the mirror, no change in the position of the latter occurs when the sub-stage fittings are moved. A mechanical stage gives an advantage for searching purposes, but it must be of such construction that the sub-stage illuminator can be racked up until the top of the latter is level with the stage. In other

Fig. 2.

requires any instrument suitable for bacteriological or pathological work can be utilized. Even the absence of centering screws from the substage may be remedied by having a centering base-piece fitted to the microscope (Fig. 3), so that the objective in use may be centred to the dark-ground illuminator. This arrangement should only be regarded as an expedient, it is not so satisfactory as the use of a centering substage.

Objectives.—The objectives may be any of the following:

8 mm. Apochromatic Dry.
4 mm. Apochromatic Dry with Correction Collar.
3 mm. Apochromatic Oil Immersion.
2 mm. do. do.
$\frac{1}{2}$ inch Achromatic.
1 25th inch do.
1 12th inch do. Oil Immersion.

The lenses here enumerated are given in order of preference. It cannot be too strongly insisted that, for dark-ground work, both from the point of view of optical theory and of practical experience, an oil immersion objective is not essential. For instance, with the 8 mm. objective and an 18 compensating ocular, specimens can be seen and demonstrated with ease and certainty. If this combination of objective and ocular is available, nothing further is necessary for an observer of moderate experience. The 4 mm. Apochromat does not need such a high ocular, although it is quite permissible to use it.

The numerical aperture (N.A.) of any objective for the purpose in view must not exceed 0·95. The N.A. of the 4 mm. Apo is therefore the utmost permissible, and with most dark-ground illuminators, even this aperture must be reduced. This is best achieved by placing a funnel stop in the

Fig. 3

objective (Fig. 3), so that the stop itself is almost in contact with the back lens. The funnel stop is simply a short tube with a constricted end which drops into the back of the objective. This is necessary to reduce the N.A. of the objective effectively. A stop of any description, such, for instance, as in the diaphragm, which is operative at any appreciable distance from the back lens of the objective, is useless, and should be avoided. All oil immersion objectives must be fitted with a funnel stop, and in those cases where they do not already, provided it can easily be obtained from an optician. It should be remembered that the funnel stop must be removed for ordinary observational purposes. The permissible N.A. is also to some extent limited by the light source used. Relatively weak illuminants allow of a larger N.A. being utilized, but this point will be further referred to when discussing the subject of illumination.

When a dry lens is used, the principal adjustment necessary is tube-length. All makers specify a certain length of tube for which their objectives are corrected, usually 160 or 170 mm., but this is dependent on the thickness of cover glass used. The thickness usually allowed for is from

0.15 to 0.18 mm. If the cover glass is thicker than this, tube-length should be reduced, if thinner the tube must be lengthened. The effect of this is easily seen, particularly with strong illuminants and high-power eye pieces. If the cover glass is not of the correct thickness or the tube length inaccurate, the image has a very definite haze surrounding it, which does not entirely disappear even when the object is in focus. The remedy is to adjust the tube-length until the image appears bright and clear with no surrounding nebulosity. This adjustment is quite easy to perform with dark-ground illumination. An alternative method is to observe any small bright particle in the field of view. When tube-length is accurate this appears as a disc of light equal in form and intensity whether the objective is above or below the focus, that is, it goes in or out of focus with the same appearance in whichever direction the fine adjustment screw is moved. If tube-length is inaccurate, it has a nebulous or misty appearance in one direction. If this nebulosity appears below the focus, that is when the tube moves downwards, tube-length must be reduced. The opposite conditions indicate that the tube requires lengthening. No objective of poor quality is satisfactory for dark-ground work, as no method of observation so accentuates faults or imperfect correction. It is necessary therefore to make sure by ordinary testing methods, or by submitting the lens to a competent observer that it is of sufficiently good quality for the purpose in view.

It is recognised, however, that in most bacteriological outfits the 1/12th inch oil immersion objective is the only one likely to be usable, few 1/6th inch objectives being of sufficiently good quality. By the use of a low-power ocular (× 6 or × 8) careful attention to centration, and the provision of a suitable stop, this may be satisfactorily utilised for the purpose in view.

A list of lenses of the Royal Microscopical Society is now being prepared, to whom reference may be made for assistance in this matter or for help in setting up and adjusting microscopic apparatus. Enquiries may be addressed to the Medical Research Committee or to the Secretary of the Royal Microscopical Society, 20, Hanover Square, London, W.

Concise instructions for the use of any available apparatus may be obtained from Mr. J. E. Barnard, Lecturer in Microscopy, University of London, King's College, or demonstrations may be arranged by appointment.

Oculars. If Apochromatic objectives are used, the ocular should be of the compensating type, otherwise ordinary oculars will suffice. Two oculars at least should be provided, a low-power one (circa × 4) for adjusting and centreing the dark-ground illuminator, and a high power one (× 8 to × 18) for observational purposes.

Cover Glasses and Slides. The cover glasses used must be of good quality free from blemishes or scratches. At the present time these are not easy to obtain, but to secure the best results with any save immersion lenses a cover glass which is free from surface defects is essential. Examination of the surface with a low power objective, say a 2/3 inch, will demonstrate its suitability or otherwise at once. The glass surface should be illuminated with incident light at an angle of about 45° to the normal. If gross defects are present they will at once become evident. The slides should be of the thickness specified by the maker of the dark-ground illuminator. The limits of error should not exceed 0.1 mm. Slides of 1 mm. are the thinnest usable, and 1.2 mm. is about the limit of thickness. When an oil-immersion objective is used, the thickness of cover glass is unimportant provided that it is not too great for the objective to focus through; neither is it so essential to ensure that the cover glass is free from defects, as many of these consist of irregularities in the glass itself, which are not so evident when the objective is immersed. In any case it is important that both slides and covers should

be well cleaned, or otherwise it is difficult to make a thin even preparation, free from air-bubbles, on which success largely depends. The cleaning agent is provided by boiling in a glass vessel a solution of strong sulphuric acid in a saturated solution of bichromate of potash or soda (or, in the case of new glass, nitric acid). After boiling for about two minutes the slides should be well washed in running water, rinsed in distilled water, and put into alcohol, in which a few drops of strong ammonia have been added. They may be kept in the latter until required, and only need wiping with a clean rag or soft tissue paper before use. Alternatively, the cover glasses may be cleaned with absolute alcohol, using a piece of soft washed rag or an old piece of silk for the cleaning operation. In any case, the utmost attention should be given to the possibility of any small particles of grit or dirt being on the cloth, some abrasion of the cover glass surface is sure to occur, and this becomes evident in use.

The Dark-ground Illuminator.—There are three types of illuminator suitable for the purpose in view. They are as follows:—

(1) An immersion achromatic condenser with N.A. 1.25 to 1.40 is added. A stop may be applied to the sub-stage stop carrier usually provided for this purpose. (Fig. 4.)

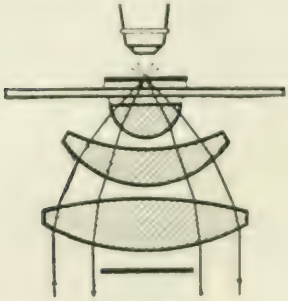


Fig. 4.

(2) A parabolic condenser, a modern of the type designed in England many years ago and recently re-introduced by Zeiss. (Fig. 5.)

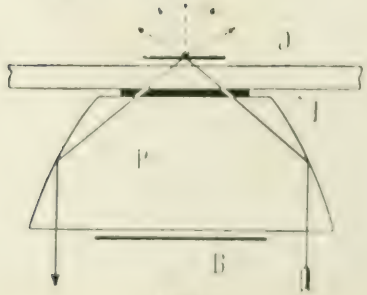


Fig. 5.

(3) The spherical surface reflecting condenser as introduced by Leitz. (Fig. 6.)

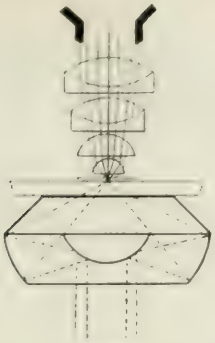


FIG. 6

The relative advantages of the three types are not particularly well marked, as any one may be so used as to produce a satisfactory result. In the first type, however, it is essential that the condenser should be one of good quality with a large aplanatic cone, that is, the condenser must be as free as practicable from chromatic or spherical aberration. Such condensers are made by Swift or Watson, and yield good results, but it is important to see that the appliance for carrying the stop is accurately

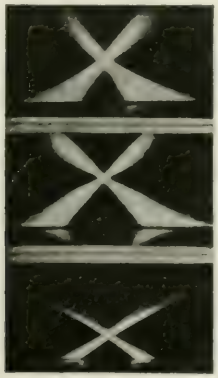


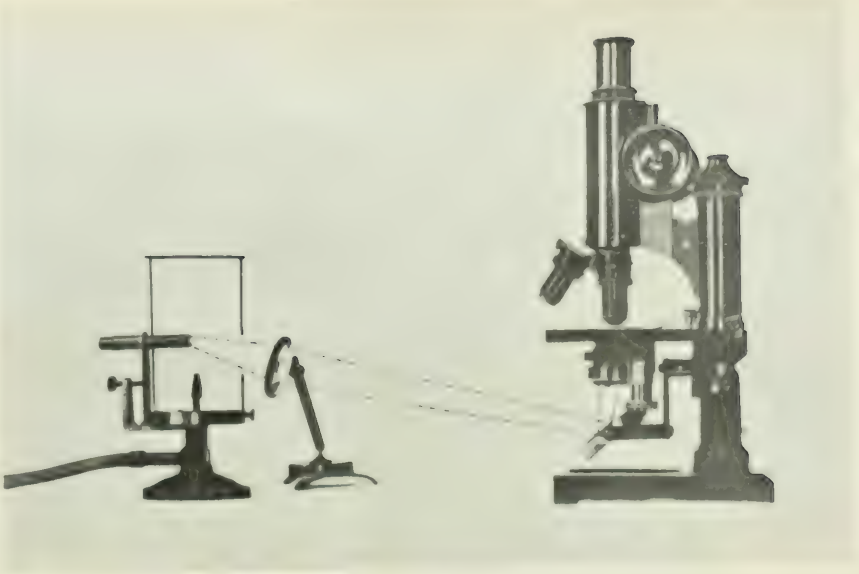
FIG. 7

Showing Path of Light in Dark Ground Illuminator

A Result of stop in Achromatic Condenser
B Spherical Surface Illuminator
C Parabeloidal Illuminator

centred to the optic axis. The size of the stop necessary is dependent on the N.A. of the objective used, but in practice it is perhaps simplest to procure a set of stops of various sizes and to use the smallest one which gives the dark-ground effect. The second type of illuminator is rather better

J. Swift & Son, Tottenham Court Road, W.



H. F. Angus & Co., of Wigmore Street, London, W. This embodies a somewhat new but very simple method. It consists of a specially made incandescent mantle which gives an intense luminous source of light of about 5 mm. across. It is sufficiently intense for seeing *Spironema pallidum*, and for differentiating it from other similar organisms. The simplest method of arranging the light for use is to set it up at one end of a board which may be about 21 inches long by 9 or 10 inches broad. In front of the light is placed the bull's eye or condensing lens (Lab. Figure 81). The position of the latter should be such that the image of the radiant is projected about 7 to 9 inches from the condensing lens. The microscope is then put at the other end of the board, so that this image of the radiant falls exactly in the centre of the mirror. The choice of type of condensing lens is not important; either the ordinary bull's eye or a bi-convex lens, not exceeding five inches in focal length, may be employed. The arrangement of the apparatus is, therefore, that the light is in a position furthest from the observer, the condensing lens being between the light and the microscope. The lens must be placed with its surface at right angles to a line joining the centre of the illuminant with the centre of the microscope mirror. In the case of paraboloidal illuminators it is important to see that the light as projected is completely filling the back of the condenser, and to ensure that a large image of the radiant is being projected the bull's eye must be fairly close to the radiant. With spherical surface condensers, the bull's eye may be somewhat further away, with the result that a smaller image of the radiant reaches the mirror. An arrangement to facilitate the adjustment of these subsidiary parts will also be supplied by Messrs. Angus & Co. in connection with the new source of light. In this the radiant and the bull's eye are mounted correctly in relation to each other. A fixed mirror is provided on the base-board in such a position that a vertical beam is projected from the mirror surface. It is then only necessary to remove the mirror from the microscope, and having placed the latter in a vertical position, to stand it centrally over the fixed mirror and satisfactory illumination results without any further adjustment of the subsidiary apparatus.

Manipulation. There are many methods of adjusting dark-ground illuminators, but the following has the merit of simplicity, and if carried out with reasonable care is sufficiently correct for any purpose. The illuminant is first set up in the manner already described with its bull's eye condenser in correct relation to the mirror of the microscope. No optical appliance is put into the microscope itself with the exception of a low-power ocular. The light is then directed up the tube so that the eye piece is evenly and completely filled with light. That this has been accomplished may be ascertained in one of two ways. If the observer places his eye exactly over the ocular and at a distance of from 8 to 10 inches from it, he will see, if the adjustment is correct, a perfectly even disc of light. A more exact method is, if the illuminant is sufficiently powerful, to project a disc of light on to the ceiling. If that is impracticable, put on to a piece of paper held two or three feet above the microscope. If there is any lack of centration, due either to the beam not being projected along the optic axis of the microscope or to the image of the source of light not falling in the centre of the mirror, it can at once be ascertained and corrected by manipulation of the mirror or alteration of the position of the light. If the board with a fixed mirror, as already described, is used, it is first necessary to shift the microscope about until satisfactory illumination is obtained, that is, until the beam passes centrally up the microscope body tube. This adjustment having been effected the next step is to clip the dark-ground illuminator into the sub-stage. Place a low-power objective in the microscope and the object on the stage, having previously put a large drop of cedar-wood oil or glycerine and water on the top of the dark-ground illuminator; carefully rack up the latter so that the under side of the object slide is immersed and is nearly in contact with the top of the dark-ground illuminator. Now get the object into focus by suitable adjustment of the objective. On observing, it will be seen that the object

is illuminated by a disc of light. By means of the sub-stage rack-work, the illuminator should be screwed up or down until the smallest possible area of the object in the field of view is illuminated. It will probably now be found that the illuminated disc is not central, and this must be corrected by the centring screws on the sub-stage, or by the fitting to the nose piece of the microscope of the latter alternative is adopted. Under no circumstances should the adjustment of the light to the microscope be interfered with after the preliminary adjustment described has been carried out. Any correction necessary to ensure centration must be effected entirely by the centring screws, either of the sub-stage or the nose-piece. The higher power dry or immersion objective which is to be used for searching purposes is now substituted for the low power one and the object again brought into view. It may be found that some want of centration is apparent, due to the optical axes of the objectives not being coincident. This again may be corrected by the centring screws. A higher power ocular may now be substituted, and the apparatus should be in perfect adjustment. It should be remembered that when using a dry lens any alteration of tube-length necessary to correct for different thicknesses of cover glass must be effected, and this should be the final operation.

It is well worth while to procure a simple micrometer gauge and to calibrate both cover glasses and slides before using anew. By the use of such a gauge, the trouble incidental to correction by means of alteration of tube-length is avoided. These can be obtained from any optician, but a thoroughly satisfactory substitute is that made for engineering purposes and sold by most tool dealers. These read to 1/1000th of a millimetre with accuracy, and are preferable to the cheaper form of gauge with a long lever arm which is sold for optical purposes, and which is very easily put out of adjustment should the arm be knocked or bent.

Absolute cleanliness is one of the main conditions for successful manipulation. The cover glasses and slides must be dealt with in the manner already described, and both objectives and oculars should be kept free from dust. If operations are carried out in a room where dust is prevalent then it is advisable, if a dry lens is used for observational work, to carefully dust the cover glass with a small camel-hair brush. The stage of the microscope and its rack-work should be carefully dusted over with a duster. This should be done before the commencement of any work, and not during the progress of it. Finally, the microscope should be covered with a cloth when not in use.

The examination should be carried out in a room which is not too brightly illuminated, as the pupil of the eye will then contract, and the field of view will be darkened. Absolute darkness is not essential, as in fact it is doubtful whether it is advisable. In no case should the microscope be placed opposite a lighted window or in any position where a strong light falls upon the eye of the observer.

The examination fluid used with any illuminator must be free from air-bubbles. A method of avoiding this is to place a large drop of oil or glycerine and water on the top surface of the illuminator. Also place a small drop of the fluid on the upper side of the object-glass. See that the illuminator is low enough down to avoid contact of the drops when the slide is placed on the stage. Now carefully raise the illuminator until the two drops touch. Owing to the convexity of the contact surfaces of these drops, there is no tendency for air to be enclosed, and the result invariably is that an air-free immersion is secured.

5. *Stained Films.*

In the last few years, which followed the discovery of the *S. pneumoniæ* (Pneumococcus), stained films have been employed almost exclusively for diagnostic purposes. They have also been largely replaced by other methods.

To obtain good results it is important in the first place that the material for film-preparation be properly fixed, preferably by absolute alcohol, methyl alcohol or picric acid. The film should be fixed as soon as dried.

It is the experience of the Commission that the Romanowsky staining in one of its modifications affords the best results, more particularly Leishman's long method, although Leishman's and Hastie Wright's modifica-

tions are not far behind. By these methods *Spironema pallidum* is coloured a rose pink, while other spirochaetes are blue in colour.

Methods.

(1) *Giemsa's ordinary or slow method.* Staining for 12 hours with a 1-in-10 to 15 dilution in tap water.

(2) *Giemsa's rapid method.* In this method the same dilution of stain is used, only the stain is poured on the slide and the slide held over a Bunsen burner until steam rises. The process is repeated 3 or 4 times, the final application lasting 2 minutes.

(3) *Leishman's method.* As recommended by the author.

3. *Indian Ink and Congo Red Methods.*

Of all the methods devised for the demonstration of the *Spironema pallidum* these are certainly the simplest in that no special apparatus or complicated stain is necessary. The advantages, as will be pointed out later, are more than counterbalanced by certain inherent defects.

Indian Ink Method (*Burri*). For use, a drop of the fluid to be examined is mixed with one drop of the Indian ink on an ordinary microscopic slide and spread in a thin film, as in the making of a blood film. The film is then dried in the air without heat, and when dry examined under the 1/12 oil immersion.

The *Spironema pallidum* by this method appears as a white undulating thread against a dark (i.e., yellowish or dark brown) background.

Congo Red Method (*Burri*). Here 2 per cent. Congo Red solution replaces the Indian ink. When the film has dried, it is flooded with acid alcohol, whereby the background is converted into a semi-opaque blood purple, against which the clear unstained spirochaetes stand out in sharp contrast.

Advantages and disadvantages.—These methods, although very useful for demonstrating other spirochaetes, cannot be recommended for the detection of *Spironema pallidum*, and this because:

(1) The width of the spirochaete varies according to the thickness of the film; in a thick film it is seen as a fine filament, in a thin film it appears thick.

(2) There is a liability to great distortion of the spirochaetes.

(3) The characteristic movement of the spirochaetes cannot be observed.

The only advantage of the methods is their great simplicity. It is, however, to be questioned if, in the hands of inexperienced workers, they can lead to any appreciable degrees.

4. *Silver Nitrate Methods.*

From time to time different writers have recommended silver nitrate solutions for staining the *S. pallidum*, but after a few trials they were mostly found to be unreliable. Recently, however, Fontana[1] has introduced a method which gives much more successful results. The preparation after fixing is mordanted with a solution containing tannic acid, treated in water and stained with an ammoniacal solution of silver nitrate.

The following are the details of the method as modified and improved by Tribondeau[2]:

[1] Fontana, A. *Dermat. Wchnschr.* Leipz., 1921, **55**, 1001.

[2] Tribondeau, *Bull. Soc. franç. de dermat. et syph.* Par., 1921, **23**, 5.
Ibid. Ann. de l'Inst. Pasteur, Par., 1919, **31**, 1.

These solutions are used in the process as follows: (1) a strong solution, (2) a weak solution. It is of the utmost importance that all glassware employed in the process should be chemically clean.

(1) Formol-acetic acid [Rüge's solution]. Acetic acid, pure, glacial, 1 part; formalin [40 per cent.], 2 parts; distilled water, 100 parts.

(2) Tannin mordant, or tannin, 2 grm.; distilled water, 100 c.c. Dissolve the tannin in the distilled water and preserve from undue contamination in a well-stoppered bottle with a small piece of camphor.

(3) Silver solution [Cajal's solution]. Silver nitrate, 1 gram; distilled water, 20 c.c. Dissolve the silver nitrate in the cold. After solution is complete a quantity is placed in a perfectly clean stoppered measure, and by means of a pipette ammonia is added drop by drop, the mixture being frequently shaken. At first a brownish precipitate appears, gradually becoming darker [more generally reddish]. A point comes when the precipitate begins to dissolve; then the ammonia, preferably diluted, should be added very cautiously, and it is necessary to stop when the fluid is still very faintly opalescent. If this stage has been inadvertently passed a small quantity of the silver nitrate solution should be added until the desired opalescence is reached and maintained on shaking.

Technique. Films are made in the usual way and fixed in alcohol. Pass to the formol-acetic solution, which is poured on and off once or twice, a fresh quantity being left on for 1–3 minutes. It is to the greatest importance that fixing fluid which may be present in tissue components in the film should be completely washed out by the solutions. In the case of sections or squashes about the 20th should be washed with absolute alcohol. Smears may, on the contrary, be washed with distilled water and finally alcohol. After treatment by the formol-acetic solution the preparations are then covered with the tannin mordant, and heated gently till vapour rises [not boiling]. The mordant is left on for 30 seconds.

Wash thoroughly under the tap for 30 seconds, and rinse by a wash bottle of distilled water.

Drain on the silver solution and allow it to act for a few seconds in the cold. Pour off and add a fresh quantity of silver solution and heat gently till vapour arises. Leave the silver solution to act for a further 15 seconds. Rinse over the film in a watch-glass (Rüge).

Wash in a beaker [not tap] water for a few seconds, dry with filtering paper.

Some leaves [not stained yellow] in Canada balsam (Rüge), and stand on very sharply.

Thin sections may be examined directly, but they should not be left in the oil as the oil destroys the preparation. The film can be safely mounted in neutral glycerine under a thick glass [Hämatoxylin or in Canada balsam dissolved in xylol (Fusari)].

Advantages and disadvantages of staining methods. Admittedly, well-stained preparations afford characteristic appearances, where that is the reason are genuine. One cannot be questioned. On the other hand, the impregnation process has a notable lack of utility for most staining purposes. As a result, material which by other methods yields numerous preparations may fail to yield these by impregnation, or but an occasional well-stained one may be made out, thus affording an erroneous idea of their frequency. So also the Argentine method for staining the fibrillæ of the chromophile neurones, see Bielschowsky's method, etc.

III. — Soft Chancre and Balanitis.

The Committee find no sufficient evidence that what is clinically known as "soft chancre" or "soft sore" is a specific disease induced by a single species of micro-organism.

In these circumstances they recommend that a diagnosis of soft chancre be founded on clinical evidence, and this only after syphilis has been excluded by observation extending over a period of twelve weeks. A similar recommendation is made with respect to conditions of balanitis.

APPENDIX I. — *On the Resolving Power of the Microscope.*

It is necessary to appreciate that increased visibility is secured by means of dark ground illumination but that resolution (that factor on microscopic object upon or which the elucidation of fine structure depends) is reduced. When an object is seen as a bright object on a dark ground it is possible to see much smaller particles than is the case by other means. If a single molecule in fact could be isolated and illuminated by a sufficiently intense source of light it would be visible. The image we would have of it would have no relation to the form or size of the object: it would be a bright circular point of light surrounded by one or more bright rings.

In all dark ground illumination work such luminous particles are seen and these may be regarded as ultra-microscopic. The number visible depends almost entirely on the intensity of the illuminant and this constitutes still another reason for avoiding the various light sources where the object is to demonstrate the presence of an organism which is within the limits of resolution of the microscopic objective employed.

Resolving power is dependent on two factors — the numerical aperture (N.A.) of the objective and the wave length of the light used.

It is therefore evident that increased resolution can only be secured by increasing the N.A. of the objective or by decreasing the wave length of the light employed. In the present state of knowledge there is no practical use of objectives having greater N.A. than is now available but there is a very wide field for the use of light of shorter wave length, such as ultra-violet light, or other invisible radiations. In dark ground work, bacteria and similar translucent objects, which appear to be stained, may be visible by ordinary methods of observation, are easily shown, but there are well within the limit of resolution. An object which is less than 0·2 μ in diameter is beyond the limit of resolution by transmitted light of average wave length. As it is impossible to utilise the full N.A. of a dark ground condenser, objects to be dark ground methods the limit is reached at a considerably larger object by the latter method.

APPENDIX II. — *On the Nomenclature of the Spirochaetæ of Syphilis.*

By Clifford Dobell, F.R.S.

The organism was discovered and first named by Schaudinn (1905), who called it *Spirochaete pallida*. (The name was proposed by Schaudinn in a preliminary note.) Hoffmann (1905) and Siegel (1905) also described it. Schaudinn and Hoffmann (1905) and Siegel (1905) also described it. The specific name of the organism is therefore *pallida* (Schaudinn, 1905) Siegel, 1905.

The genus name *Spirochaeta* (Ehrenberg, 1835) Schaudinn, 1905, is available (problems first connected to which two genera mentioned were *Spirochaeta* Ehrenberg, 1835 [Ehrenberg's description of the genus is *S. plicatilis* Ehrenberg] and *Cristispira* Bütschli, 1876). Although the two genera are quite distinct, like the syphilis spirochaete that the latter cannot be placed in the same genus.

As the organism cannot be retained in the genus *Spirochaeta* Ehrenberg, another name must be found for it. Hitherto proposals to place it in the genera *Treponema* Schaudinn, 1905, and *Microspironema* Stiles and Pfender, 1905, have been made. *Treponema* Schaudinn, 1905, is based upon characters which are not distinctive, and need not be considered further. *Microspironema* Stiles and Pfender, 1905, is a synonym of *Cristispira* Bütschli, 1876, and is therefore invalid. The name *Spirochaeta* is the oldest available name for the genus, and must be used.

The three names proposed for the syphilis spirochaete are:

(1) *Spirochaeta pallida* Schaudinn, 1905.
(2) *Treponema pallidum* Schaudinn, October, 1905.
(3) *Microspironema*, proposed by Stiles and Pfender in December, 1905.

(1) The name *Spirochaeta pallida* has priority over *Treponema pallidum* and is therefore the correct name, unless it can be shown to be unavailable. It was proposed by Schaudinn to replace *Spirochaeta* on the ground that the latter is a synonym of *Cristispira*. However, since the opinion is now held by many that *Spirochaeta* is a valid genus, Schaudinn's reason for proposing a new name disappears, and the name *Spirochaeta pallida* is the correct one.

(2) *Treponema pallidum* is a synonym of *Spirochaeta pallida*, and is therefore invalid.

(3) *Microspironema* is a synonym of *Cristispira*, and is therefore invalid.

EXPLANATION OF PLATES III., IV., AND V.

[PLATE III.]

Figure 1 and 2. *S. gallicus*. Collected from rocks with the above fauna. Natural size.

Figure 3. *Spirorbis* (*Circeis*) *spirillum* (Linn.). Collected with *S. gallicus* on a piece of the sponge *Axinella damicornis*. Enlarged about 6 diameters. Compare with *S. gallicus* (Fig. 4), on same piece of sponge. Note the form of the whorls of the tube. It is also more depressed.

Figure 4. Shell and operculum of same as Fig. 2, enlarged about 6 diameters. Normally specimens are much paler in colour, and a darker pigmentation forms *S. gallicus* Fig. 2.

Figures 5 and 6.—Spirochaetes from genital sores, coarser, much less regular and more refringent than *S. pallidum*.

Figure 7.—*S. dentium* from mouth. Coils tightly rolled and not open as in *S. pallidum*.

Figure 8.—*S. dentium*. This form is almost impossible to distinguish from *S. pallidum* under dark ground illumination, but its movements are rather stiffer and its coils more angular.

Figure 9.—Spirochaete from mouth. Coarser and much less regular than *S. pallidum*. Very similar to the organisms shown in Figures 5 and 6.

PLATE IV

Figure 1.—*S. pallidum*. Enlargement of Plate III, Figure 4.

Figure 2.—Enlargement of Plate III, Figure 5. Emphasises the greater thickness which distinguishes this spirochaete from *S. pallidum*.

PLATE V

Figure 1.—*S. dentium*. Enlargement of Plate III, Figure 7. Comparison of this with Plate IV, Figure 1, shows the tighter rolling of the coils in comparison with those of *S. pallidum*.

Figure 2.—*S. dentium*. Emphasises the greater angularity of the coils of this spirochaete in comparison with those of *S. pallidum* in Plate IV, Figure 1.

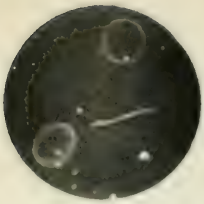


Fig.1.

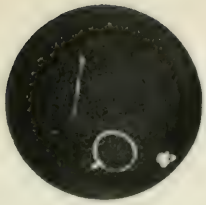


Fig. 2.

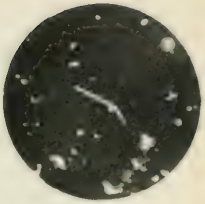


Fig 3.

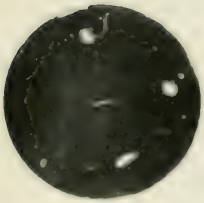


Fig.4.

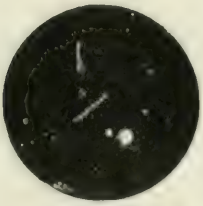


Fig.5.

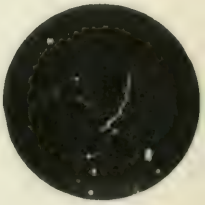


Fig.6.

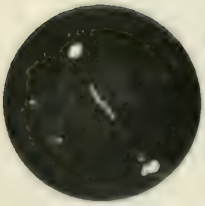


Fig.7.

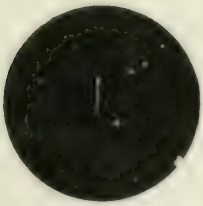


Fig 8

Fig 9

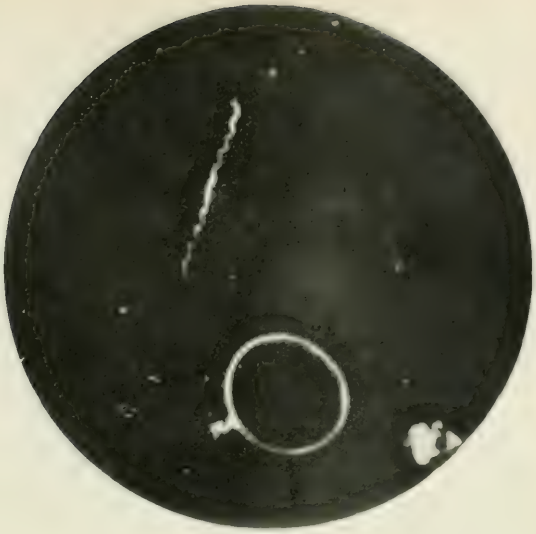


Fig. 1.

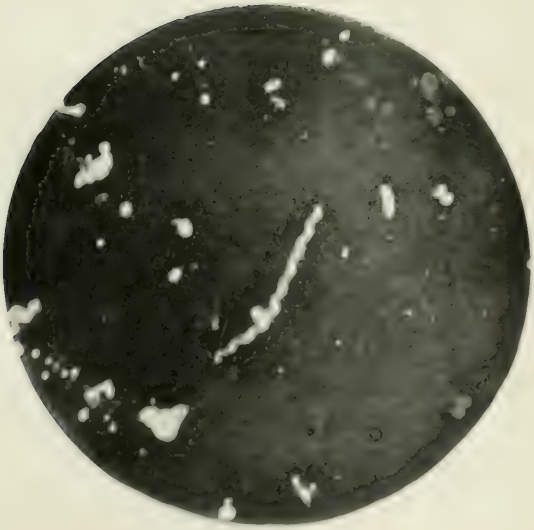


Fig. 2

Fig. 1.

Fig. 2.

Special Report Series, No. 20.

NATIONAL HEALTH INSURANCE.

MEDICAL RESEARCH COMMITTEE.

A Study of Social and Economic Factors in the Causation of Rickets.

With an Introductory Historical Survey.

LONDON
PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE.

To be purchased through any Bookseller or directly from
H.M. STATIONERY OFFICE at the following addresses
IMPERIAL HOUSE, KINGSWAY, LONDON, W.C. 2, and 28, ABINGDON STREET, LONDON, S.W. 1.
37, PETER STREET, MANCHESTER; 1, ST. ANDREW'S CRESCENT, CARDIFF;
23, FORTH STREET, EDINBURGH;
or from E. PONSONBY, LTD., 116, GRAFTON STREET, DUBLIN

1918.

Price 2*s. net*

MEDICAL RESEARCH COMMITTEE.

The following publications relating to the work of the Medical Research Committee can be purchased through any bookseller, or directly from H.M. Stationery Office at the following addresses: Imperial House, Kingsway, London, W.C. 2, and 28, Abingdon Street, London, S.W. 1; 37, Peter Street, Manchester; 1 St. Andrew's Crescent, Cardiff; 23, Forth Street, Edinburgh; or from E. Ponsonby, Ltd., 116, Grafton Street, Dublin.

First Annual Report of the Medical Research Committee, 1914-1915. (Cd. 8101.) Price 3*d*., post free 4*d*.

Second Annual Report of the Medical Research Committee, 1915-1916. (Cd. 8309.) Price 3½*d*., post free 5*d*.

Third Annual Report of the Medical Research Committee. (Cd. 8825.) Price 6*d*., post free 7*d*.

Special Report Series.

No. 1. First Report of the Special Investigation Committee upon the Incidence of Phthisis in relation to Occupations. The Wood and Shoe Trades. Price 3*d*., post free 4*d*.

No. 2. Report of the Special Advisory Committee upon Bacteriological Studies of Cerebro-spinal Fever during the Epidemic of 1915. Price 6*d*., post free 7*d*.

No. 3. Bacteriological Studies on the Pathology and Preventive Control of Cerebro-spinal Fever among the Forces during 1915 and 1916. Price 1*s*. 6*d*., post free 1*s*. 8*d*.

No. 4. Reports upon Investigations in the United Kingdom of Dysentery cases received from the Eastern Mediterranean.

I. Amœbic Dysentery, and the Protozoological Investigation of Cases and Carriers. Price 1*s*., post free 1*s*. 2*d*.

No. 5. II. Report upon 878 Cases of Bacillary Dysentery. Price 1*s*. 6*d*., post free 1*s*. 8*d*.

No. 6. III. Report upon Recovered Cases of Intestinal Disease in the Royal Naval Hospital, Haslar, 1915-16.

IV. Report upon Combined Clinical and Bacteriological Studies of Dysentery Cases from the Mediterranean. Price 1*s*. 6*d*., post free 1*s*. 8*d*.

No. 7. V. Report upon 2,360 Dysentery Convalescents received at Liverpool from various Expeditionary Forces. Price 2*s*., post free 2*s*. 2*d*.

No. 8. Report upon Soldiers returned as Cases of "Disordered Action of the Heart" (D.A.H.), or "Valvular Disease of the Heart" (V.D.H.). Price 1*s*., post free 1*s*. 2*d*.

No. 9. A Report upon the use of Atropine as a Diagnostic Agent in Epidemic Dysentery. Price 1*s*., post free 1*s*. 2*d*.

No. 10. The Mortalities of Birth, Infancy, and Childhood. Price 1*s*. 6*d*., post free 1*s*. 8*d*.

No. 11. The Causation and Prevention of Dysenteric Infection (A.N.Y.) Processes. Price 1*s*., post free 1*s*. 2*d*.

No. 12. The Classification and Study of the Anaerobic Bacteria of Wound Infection. Price 1*s*., post free 1*s*. 2*d*.

NATIONAL HEALTH INSURANCE.

MEDICAL RESEARCH COMMITTEE.

A Study of Social and Economic Factors in the Causation of Rickets.

By Margaret Ferguson, M.A.

(Working under the direction of Dr Noel Paton and Leonard Findlay)

With an Introductory Historical Survey

By Leonard Findlay

(From the Physiological Laboratory, University of Glasgow)

(Approved for publication by the Medical Research Committee, 12th October 1917.)

Medical Research Committee.

(National Health Insurance.)

The Hon. Waldorf Astor, M.P. *(Chairman.)*

The Right Hon. Christopher Addison, M.D., M.P.

The Viscount Goschen, C.B.E. *(Treasurer.)*

C. J. Bond, C.M.G., F.R.C.S. (Hon. Colonel).

A. K. Chalmers, M.D., D.P.H. (Lieut.-Colonel R.A.M.C. (T.)).

Professor William Bulloch, M.D., F.R.S.

Professor F. G. Hopkins, D.Sc., F.R.S.

Colonel Sir William Leishman, K.C.M.G., C.B., F.R.S.

Professor G. R. Murray, M.D., F.R.C.P. (Major R.A.M.C. (T.)).

Sir Walter M. Fletcher, K.B.E., M.D., F.R.S. *(Secretary).*

15, Buckingham Street,
Strand, W.C. 2.

(B2211) Wt. 1841—148 (F). 1/20. 3/28. Sir J. C. & S. **Gp 32.**

INTRODUCTION.

At the beginning of their work the Medical Research Committee arranged at various university or municipal centres co-ordinated schemes of enquiry into the causation of rickets. The outbreak of war made it necessary to abandon several parts of the general plan of investigation, but it has fortunately remained possible to maintain, in spite of many handicaps, the group of enquiries which Professor Noël Paton, Professor Muir and their colleagues at Glasgow had originally undertaken to prosecute on behalf of the Committee in a place where so many opportunities were available for this study. The work at this centre has consisted primarily in investigations of two kinds, different in method but closely related. On the one hand in the laboratory, by biochemical analysis and physiological experiment, work has been done upon tetany in children, which is a special manifestation, or at least a common accompaniment, of rickets. The Committee gave a short summary of some of the main results of this work in their last Annual Report, and a full account of them has now been published.* Other laboratory studies have at the same time been in progress with reference to other special points in the pathology of rickets. Side by side with work of this kind, on the other hand, a systematic investigation of social and economic conditions in their relation to the incidence of rickets has been undertaken, and the results gained are now given in the present Report by Miss Margaret Ferguson, who has conducted the necessary enquiries by personal visiting in suitable districts.

Miss Ferguson's Report is preceded here by a general survey of what has previously been written of the history, distribution, pathology and causation of rickets, which Dr. Leonard Findlay has been good enough to prepare in the form of an introduction to these sociological studies at Glasgow. For this the Committee are under heavy obligation to him.

These sociological studies have brought together much evidence to illustrate the relations between city life with its various urban and domestic conditions and the occurrence of rickets in children. Miss Ferguson has also been able to bring into comparison the results of visits paid to the garden cities at Bournville and Port Sunlight, where rickets is very uncommon. The Committee would desire here to express their grateful acknowledgments to the authorities at those model communities for the facilities kindly granted to Miss Ferguson for her purposes.

It will be generally admitted that sociological studies of this kind, when considered as a method of scientific work, have some special dangers of their own. With a view to experimental work in the laboratory, it is advantageous, if not necessary, for the

* *Quarterly Journal of Experimental Physiology*, 1917, pp. 10, 203, 382.

worker to start with a particular obsession or at least with some definite hypothesis in view; while his experiments will thus gain direction the appeal to experimental proof will ultimately dismiss or establish the initial idea. But in purely observational science divorced from experiment, where statistical and sociological methods are the chief means by the collection and arrangement of documents he is exposed to the danger of fallacy at the prompting in his mind of a preconception which unwittingly influences the selection of facts to be preserved for analysis. Moreover, there is a danger from another quarter, due to the absence of the real clue to the problem, lest of the facts actually collected many turn out to have been irrelevant, and their analysis to lead not so much to error as to waste of time. While these difficulties of the purely observational method must occur in full view, the Committee think it will be agreed that Miss Ferguson's collections of fact have been made wholly impartially. At the same time she has had the advantage of working under the guidance of ideas engendered upon the experimental side of the investigation. The considerations which go to set out at the end of her report have been drawn from her findings by Professor Noël Paton and Dr Leonard Findlay, acting as it were as a small jury reviewing the evidence to which she has testified.

The main contention as to the causation of rickets must always centre about the dilemma whether speaking broadly it is to be discovered in terms of diet, or in terms of other conditions of home life like those of breeding and habit. It will be seen that upon a review of the numerous factors which may be summed under these general headings Miss Ferguson's studies give the chief positive value as potent factors in causing rickets to the lack of air and exercise. What this means in terms of specific physiological processes is left unexplored, and can probably only be determined by methods of experiment. It will be seen that the weight of evidence gained in these several enquiries is against a close association between deficient diet and the rickety condition.

It was at this point perhaps that doubts may arise in some minds in relation to the necessary superiority of the purely observational method already touched upon, in a question of this kind. At all events a word of caution is certainly appropriate. In regard to rickets there is perhaps a special difficulty which would not arise in many other similar problems. We must note that in the absence of true rickets as a condition specially associated with rapid growth, it is a disorder springing from a wrong direction, so to speak, given to the processes of growth rather than from their actual cessation or repression. If for the fullest manifestation of rickety signs growth is necessary we may have the parallel fact in mind, for any reason growth as such be checked, the rickety signs may not be revealed, or may be only imperfectly revealed, even though the conditions allowing it are present. It is perhaps necessary to say that deficient diet, checking growth as such, might appear to be associated with an absence of

rickets. It will be noticed that Miss Ferguson's evidence does not point significantly to differences in diet whether as to energy value or protein content or fat supply, being correlated with the presence or absence of rickets.

The Committee have already given in their last Annual Report a short statement of the results of work which Dr. Edward Mellanby has been doing at London and at Cambridge in the study of experimental rickets. This work is now being prepared for publication, and the results indicate that the primary cause of rickets is a defect of an accessory factor in the food in some respects similar to the accessory factors which have been shown in recent years to be of paramount importance in determining the rate of growth, and in preventing diseases like scurvy and *beri beri*. The anti-rachitic substance was found in highly variable degree in two chief classes of food stuffs extractives and fats. Of fats the most potent anti rachitic was butter, while some common vegetable fats contain little or none of the anti-rachitic substance. While by no means precluding lack of exercise as an additional causative factor in rickets, Dr Mellanby's work indicates that when the diet is fully adequate, lack of exercise alone will produce no rachitic symptoms.

These findings seem to be opposed to the results gained at Glasgow and mentioned on page 97 of this Report. By the courtesy of Professor Paton and Dr. Findlay the Committee learn that the latter has recently carried out further experiments which support the view that lack of exercise rather than a deficiency in diet is the determining factor for rickets in dogs. The future will no doubt explain these diversities of experience but it has been made clear that all experimental studies must now involve a close scrutiny of qualitative as well as of quantitative dietetic factors.

If in the causation of rickets we are concerned not with dietetic deficiency as to amount and general quality so much as with the presence or absence of a specific substance needed for the normal "quality" of growth, this view is not necessarily opposed as might at first appear by the conclusions drawn from Miss Ferguson's report. For instance in her tables of the Average Consumption of Food (p. 981) in rickety and non-rickety families respectively, though there seems at first sight to be no significant difference, yet on examination it will be noticed that the rickety families do appear to consume more of those articles of diet which allow rickets to develop, and less of those substances preventing rickets for instance they are found to eat more dripping, potatoes, sugar and oatmeal, and less milk, meat, butter, fish, eggs and cheese. It is true that the figures given are not widely different, but it would be hard to deny that the difference might be sufficient to upset a poised balance. The difference, moreover, might be expected to be greater in actual practice in the case of children with the more careless parents, for these might be expected to get less than

their share of the good things available. The absence of observed relation between energy value or protein content and the causation of rickets is not significant from this point of view, for while there is no experimental evidence for such a relation, it has already been pointed out that under feeding as such may hinder the manifestation of rickets inasmuch as it hinders active growth. On the other hand, Miss Ferguson has recorded the development of rickets in several children fed entirely at the breast, and though little comment upon this is made in the report, the well attested fact is not easily explained at first sight in terms of an "accessory factor" theory like that to which Dr. McHaddy's work points, and it well deserves close experimental study. It suggests at once a further investigation into the relation of the mother's diet to the condition of the breast fed infant. It is well known, of course, that an animal fed on a diet ample in quantity but deficient in "accessory factors" cannot rear her young, and it would appear that the mammary gland cannot manufacture these factors if they are missing from the food.

Of the various conditions to which the causation of rickets have been ascribed, research has still to distinguish between actual determining factors and those conditions which are merely contributory to the disorder. In the meantime Miss Ferguson's sociological work will remain as evidence of existing relationships, and no doubt fresh points of interest will be discerned in her interesting report in proportion as knowledge advances and as illumination is thrown upon the various aspects of the difficult problems involved. The Committee would desire to express their great indebtedness both to her for her labours and to Professor Noël Paton and Dr. Findlay for the stimulus and supervision they have given to this work at Glasgow.

MEDICAL RESEARCH COMMITTEE,
15, BUCKINGHAM STREET,
STRAND, W.C. 2.

June 1st, 1918.

CONTENTS.

I.—Historical Survey.

By Leonard Findlay.

1. Definition 9
2. History 9
3. Rickets in the Lower Animals 14
4. Geographical Distribution 15
5. Prevalence 17
6. Age Incidence 18
7. Sex Incidence 20
8. Seasonal Incidence 20
9. Symptoms 21
10. Pathological Changes 26
(i) *Changes in the Bones* 26
(ii) *Changes in Muscles* 36
(iii) *Changes* 39
11. Etiology 39
(i) *Heredity* 39
(ii) *Diseases of Parents* 39
(iii) *Defective Hygiene* 41
(iv) *Literature of Some Industrial Societies* 42
(v) *Method of Previous Investigators* 43
(vi) *General Conclusions* 43

II.—A Study of the Social and Economic Factors in the Causation of Rickets.

By Margaret Ferguson.

1. Object, Methods and Material 45

2. Family History 48
(i) *Previous Cases in Cognate Lines* 48
(ii) *The Mother* 49
(a) *Health* 49
(b) *Habits* 52
(iii) *The Father* 53
(a) *Health* 53
(b) *Habits* 53

3. The Rickety Child 54
(i) *Sex* 54
(ii) *Age* 54
(iii) *Previous Health and Mode of Life* 55
(iv) *Seasonal Incidence* 56

(3) *Personality Traits* 56
(4) *Condition of the Mouth* 58
(5) *Oral Effects of the Overconsumption of Alcohol* 59
(a) *Effects on Gum and Periodontal Tissues* 59
(b) *Oesophageal Cancer* 61
(c) *Malignancies of Structures or Loci of Oral Origin Following* 61
(d) *Dietary Effects* 63
(e) *Exacerbation of the Oral Consequences of Nutritional Deficiencies* 63
(6) *Liver Disease* 71
3. *The Ancient Family* 74
(1) *The Position of the Ancient Child in the Family* 74
(2) *Size of the Family* 74
(3) *Frequency of Oral Disease in the Family and Response to Disease* 75
5. *Income and Expenditure* 78
(1) *Income* 83
(2) *Expenditure* 76
6. *Housing* 87
(1) *The Quality of Environment* 87
(2) *Housing in Relation to Childhood Disease* 88
(3) *The Influence of Social Aspirations on Personal Standards* 90
(4) *Cultural and Psychological Factors* 90
(5) *Attitudes of Parents to Children* 91
(6) *Attitudes to Sugar and Disease* 92
(7) *Considerations for Dietary* 93
7. *Immunity and Host Resistance—A Consideration and Classification of Factors* 97
(1) *Oral Secretions* 97
(2) *Health of the Epithelium* 98
(3) *Conditions of Tissue* 98
(a) *Pulp Sensitivity* 98
(b) *Susceptibility* 99
8. *Conclusions* 104
9. *Summary* 105

III. GENERAL CONSIDERATIONS

(1) *By* Neil Petrie *and* Leonard Findlay

1. *Introductory* 97
2. *Dietary* 98
(1) *Universal Supplementation* 98
(2) *Diet* 99
(3) *Education* 99
(4) *Legislation* 99

I. HISTORICAL SURVEY.

By Leonard Findlay.

In this, as in most civilised countries, rickets is one of the most common diseases of childhood. Further, it is probably the most potent factor in interfering with the efficiency of the race. It not only stunts the growth and causes deformities, some of which greatly increase the dangers of child-bearing in the female, but it raises considerably the mortality rate of such diseases as measles and whooping cough, and is responsible for the rejection annually of a not inconsiderable number of army recruits. Hence no apology is needed for the following detailed statement of a somewhat extensive research designed for the elucidation of its etiology. Before presenting the results of the present investigation, however, it may be permissible, and in many ways advisable, to give, by way of introduction, a *résumé* of the facts which may be gleaned from previous studies of this disease.

1. Definition.

Rickets may be defined as a disease, the chief manifestation of which is to be seen in growing bone in which there is an excessive and irregular development of its earlier stages with arrest or delay in the formation of fully formed, firm and eventually calcified bone. In the words of Sir William Jenner* "there is excessive formation of the structure which precedes or forms the nidus for ossification, there is retardation and incomplete performance of the process of ossification." The bony tissue produced is osteoid, not osseous, and is very deficient in calcium. This poverty of the bones in calcium has rightly or wrongly within recent years caused most of the interest in rickets to centre round the question of calcium metabolism.

2. History.

The earliest undoubted description of rickets that I have been able to obtain dates from the first century of our era, and is to be found in the work on *Diseases of Women* by Soranus Ephesius† who lived between 98 and 138 A.D. According to Suidas, Soranus Ephesius, the son of Menander and Phoebe, lived some time at Alexandria, practised as a physician at Rome in the reigns of Trajan and Hadrian, and composed many beautiful books.‡ So interesting are his remarks, not only in their mode of expression, but also concerning the nature, probable cause and distribution of this disease at his time, that I will quote his

* Jenner *On Rickets* [1849] (*Medical Classics*, October 1895).

† A German translation of this work was published by H. Ilberg and J. Ch. Huber as the first of a series of Berlin Greek texts under Kaibel. It is entitled *Das Gynäkologie*. Munich, 1894.

‡ Quoted by Barbour, *Index Compendium of Ancient Authors*, Edinburgh, 1888.

words in full. For the translation of the Greek text I am indebted to Miss Donaldson, M.A., B.A. (Lond.)

"*How should the child be trained in standing and walking?*"

"When the infant makes attempts to sit down and stand up, one must assist his movements. For should he show eagerness to sit sooner than is right or too often, he becomes hunched, owing to the backbone bending while as yet the body has no sinews to resist the strain. If he continue to stand up with growing impetuosity, and wish to walk about, his legs commonly become twisted at the thighs."

An interesting chapter has the following title—

"*Why the majority of Roman children are distorted.*"

"This is observed to happen more in the neighbourhood of Rome than in other places. Some suggest as a reason that the city is undermined by cold waters and that there (*i.e.* the children's) bodies are easily chilled. Others suggest the frequent sexual intercourse of women, or intercourse taking place after a drunken bout. The truth of the matter lies in inexperience with regard to the rearing of children, for women in the city have not so great a love for their children as to have regard to every particular as the women of purely Greek stock do. If no one oversees the infant's movements his limbs do in the generality of cases become twisted, for the whole weight of the body rests on the legs, and the floor or pavement on which he walks is hard and unyielding, being for the most part laid with stone. When, therefore, he rests upon a hard substance, the weight pressing on the limbs is great, and the limbs which bear him up are frail; the limbs must then of necessity give way a little, since the bones are not yet stiff. Hence when he first begins to sit he must be propped up by swathings of bandages to counterbalance the ills that can gain the mastery over him, nor must he sit for long at first. As he advances further to the state of creeping and standing up for a little, then one should place him up against a wall and leave him alone. But for purposes of making him approach use a chair on wheels. Thus from a grading common growth of all the muscles he will practise walking. So much for movement."

Although Soranus states that the disease was unknown among the Greeks, certain authors have construed passages in Greek writings, medical and lay, as descriptions of the disease. Zeuxis in an article on the history of rickets draws attention to the following passage from Hippocrates' work *De Articulis*:

"Et quibus supra scriptos gibbositates est, et et costae in amplitudinem augeri necesse est, sed in anteriorem partem et pectus prorumpit, et coit latum ipsoque et difficulter spirant."* &c.

* With regard to those who are hunchbacked after the age of seven, they also do not get a fine chest or prominent breasts, but tend towards the back; their lungs become cramped through it, and they themselves have difficulty in breathing.

To my mind this passage can hardly be taken as describing rickets—the whole description is more in keeping with tubercular disease of the spine. How different is it from the direct and almost perfect description by Soranus of rachitic curvature of the bones of infants, and of the age at which this disease is most apparent.

Homer, in the *Iliad*[*], which was written 900 B.C., *i.e.*, 1,000 years before the time of Soranus, describes a Court jester Thersites as "bandy legged, lame of one foot, the shoulders rounded, arched down upon his chest, and over them his head was warped and a scanty stubble sprouted on it," which Delpeuch[†] considers a picture typical of rickets. Delpeuch, Marfan,[‡] and Bouchard all refer to the possibility of the Court jester of the ancients, and also of the middle ages, being rachitic, and draw attention to descriptions and bas reliefs of deformed dwarfs such as we find depicted above in Homer. I consider it doubtful, however, if these individuals were really rachitic. Mental deficiency was a characteristic of the Court jester, and they were adults: whereas rachitic individuals are not mentally deficient, and it is during childhood that the severe deformities are present, many being of fairly normal appearance by the time they reach adult life. Hence it is more probable that these deformed court jesters were more akin to our "village naturals," and deformed from paralysis, osteogenesis imperfecta and achondroplasia.

There is no evidence that the disease existed in ancient Egypt, although civilisation reached a high level at that time, and Barlow§ suggests that the disease was probably coeval with civilisation. Had it existed when this race was at its zenith it would most likely have been present also during its less rosy days; and yet Soranus, who, it will be remembered, spent some time in Alexandria, makes no mention of it. I have searched the translations of the available medical papyri (Ebers's "Papyrus" Brugsch "Papyrus," and London "Papyrus") and can find no reference to anything suggesting the condition. Although the symptoms of several maladies are described, the bulk of these works is devoted to prescriptions of remedies. One striking feature of the literature of the ancient Egyptians is the silence regarding child life. In spite of great specialisation of the practice of medicine in these times the branch of obstetrics was given over to midwives, and it is not unlikely that child welfare was also

* Homer, *Iliad*. Canto II. translation by Andrew Lang, &c. London, 1906. p. 28.

† Delpeuch, *De l'ancienneté du rachitisme*. La Presse Medicale No. 3, 1902. p. 27.

‡ Marfan, *Maladies de l'enfance*. Paris, 1912.

§ Barlow, *Keating's Cyclopædia of Diseases of Children*. Vol. 2, p. 224.

neglected by the physician, as has been the case, unfortunately, in our own time.

In his work* on the *Nubian Survey*, Elliot Smith states that among the excavated skeletons of ancient Egypt "it is common to find peculiar though slight bending of all the long bones. One naturally thinks of rickets as the causal agent, and it is quite possible that this suggestion may ultimately be justified; the reason for hesitation in adopting such a view is that clear unmistakable evidence of rachitic changes has not been found in human bones in any ancient cemetery in Egypt or Nubia." In a recent personal communication Prof. Elliot Smith writes that "he is extremely doubtful whether rickets ever really occurred in ancient Egypt," and he considers "that Ruffer, not being aware of the extent to which the perfectly normal femur can be curved, imagined he has found rickets in ancient remains from the Soudan." Elliot Smith drew my attention to the fact that Lortet et Lyonet described this disease in the remains of apes which had been kept captive in one of the Theban temples. Should such be indeed the case it would cause us no surprise if in modern times young monkeys kept in captivity are liable to develop rickets.

Although this disease had undoubtedly been observed and recorded again by Soemmering, it is to Francis Glisson, of anatomical fame, that we are indebted for rediscovering it, establishing it as a distinct clinical entity, and bringing it under the notice of the medical profession.†

From the preface to the first English translation (1651), published one year after the first Latin edition (1650), it would appear that by "common suffrage" Glisson, along with Bate and Regemorter, were selected to investigate and write a detailed description of the condition as they had already studied and written on the subject. The edition of 1650 appeared under the sole authorship of Glisson, since Bate and Regemorter, whose names appear with Glisson's as joint authors of the English edition of 1651, appreciating that it was Glisson who had really discovered the main points of the disease, considered that he should have the honour. Sheafe, Wright, Paget, Goddard and Power were other Fellows of the Royal College of Physicians who had written on the disease.

Glisson's treatise is a monument to English genius for all time, and one cannot peruse it without being impressed by the accuracy and thoroughness of his clinical and pathological descriptions. On these aspects of the subject there has been nothing to withdraw and very little to add.

* Archæological Survey of Nubia. Vol. II. Cairo, p. 21.

† A Treatise on the Rickets. Originally written in Latin. Translated by Francis Glisson, M.D. 1651.

‡ Woodward. London 1856.

The disease would appear to have been well known to the laity in his time as "the rickets"* and was popularly believed to have made its appearance some 30 years earlier, which probably means nothing more than that this period is the length of the average individual's memory.

Glisson drew attention to the large size of the head, the wasting of the body, thickening of the ends of the long bones, flacidity of the limbs, deformity of the chest, the rosary, and the protuberant abdomen. On *sectio* he remarks on the apparent increased size of the liver, the normal condition of the spleen, along with gaseous distension of the gastro-intestinal tract, slight enlargement of the mesenteric glands, and normal condition of the urinary tract. In his description of the thoracic contents he mentions pleural adhesions, pneumonia, empyema and phthisis, but he considers them rather complications. He remarks on the greater adherence of the dura to the calvarium as a feature of childhood and not necessarily a sign of rickets, and indicated that hydrocephalus may be a complication.

Under prognosis he states that "this disease in its own nature is not fatal." Glisson thought that the disease was due to unequal growth of the two sides of the bone in consequence of interference with the blood supply.

It should be mentioned that in 1645 Daniel Whistler, later a President of the Royal College of Physicians, published at Leyden an inaugural dissertation on rickets entitled "De morbo puerili Anglorum." From a critical investigation of the work and the historical facts related thereto, Dr. Norman Moore† holds that it does not present any evidence of original observation, and was in all probability founded on knowledge gained from the writings or conversations of Glisson and others. [illegible] "must

* The [illegible] word "rickets" is generally derived from [illegible] "to twist," in addition to which it is the present [illegible] which [illegible]

[illegible] Chapter I [illegible] Glisson [illegible] to the [illegible] of the [illegible] and remarks that "amongst the [illegible] all, [illegible] a few years [illegible] have been found to have been called by the [illegible] by another name." He [illegible] [illegible] it is [illegible] to [illegible] the [illegible] of [illegible] applications [illegible] to [illegible] and [illegible] the [illegible] of the [illegible], and then [illegible] the [illegible] the [illegible] by [illegible] that [illegible] [illegible] [illegible]

active medical minds were discussing the subject." It is possible, however, that the appearance of his work in Germany under the title *Mutter gezeiht Kopfloses* may have been responsible for the name "Die englische Krankheit" given to rickets in that country.

3. Rickets in the Lower Animals

Rickets occurs spontaneously in the lower animals and as a rule just as in the human subject when they are kept under unnatural conditions. It is the fact of the absence of the disease in animals living under natural conditions and its occurrence when they become the associates of man that induced Hausemann to speak of "domestication" as the cause, using the term in its broadest sense.

The earliest known example of rickets in man or the lower animals occurred in the ape. As previously mentioned (p. 12) Lortet found evidence of rickets in the remains of an ape which had been kept captive in one of the Theban Temples. Hausemann records that young monkeys kept confined in Japan, where the disease is most uncommon, become rachitic. Rickets has always been a scourge in Zoological Gardens, so much so that it is scarcely possible to rear young carnivora in captivity without their developing the disease. Bland Sutton maintained that it was possible to do so if a sufficiency of fat was provided in the diet, and it was this work which gave and still gives support to the idea that the cause of the disease is a dietetic error. I am informed, however, by those in charge of such institutions that no amount of fat will hinder the development of the disease which is still prevalent. A number of examples of rickets occurring spontaneously in animals, e.g. horse, sheep and dog, have been recorded, and in most cases where details of the conditions under which the animals were reared are available confinement would seem to have been the striking feature. In this connection some instances which have come to my own knowledge may be given.

Dr John Fergus, of Glasgow, at a discussion on the question of the etiology of rickets, before the Glasgow Medico-Chirurgical Society, related how during the summer his son and niece each had a fox terrier pup of the same breed and of about the same age. His son was able to run about with his pet and thus it obtained plenty of exercise but his niece, who was unable to do this, had her favourite tethered to a garden seat in order that she might always have it by her. Both were fed exactly alike so far as could be ascertained, and the only difference in the treatment of the two animals seemed to be in the amount of the exercise allowed. By the end of the summer the boy's dog was a fine healthy animal, whereas that of the little girl had become so deformed from what Dr Fergus described as rachitic curvature of the bones that it had to be destroyed.

The following is an extract from a letter which I received from a farmer on the West Coast of Ireland :—

> "I have learned of a case of rickets in a pup about which I am sure you would like to hear. This pup was fed on a perfect food—new milk, but from the very start was kept confined in the bottom of a barrel, where it was quite impossible it could exercise itself. One swallow does not, of course, make a summer, and one case of the kind does not prove that rickets is caused by want of exercise, but in the light of your investigations, and the great rarity of this disease in the West of Ireland (I have never seen a case of rickets in the West of Ireland in man or beast), has weight."

Through the son of another farmer in Ireland I learned that his father had noticed that during the winter rickets occasionally developed in sheep which were housed in sheds, whereas those left on the hills, though not so well fed, never showed the slightest trace of the disease.

A striking feature to be noticed in this aspect of the subject is the varying susceptibility of different animals to the disease. It has never to my knowledge been met with in the cat, which immunity Hansemann ascribes to the impossibility of domesticating this animal. Though the cat may live in the dwellings of man it is allowed a degree of freedom which is granted to no other animal. Of dogs, large breeds, *e.g.*, collie and bull dogs, are most susceptible, the smaller breeds being much less so. This is a point of no small importance in connection with experimental rickets, as dogs are almost invariably used. It is no less important too, as will be pointed out again when considering the various theories of etiology (p. 43), that since dogs when living under unsuitable conditions are prone to the disease, particular attention must be paid to this factor when adjudicating the value of any experimental results.

4. Geographical Distribution.

Rickets would seem to be a disease that is almost entirely limited to the Northern Hemisphere and to have its home in the temperate zone and chiefly between the latitudes of 40 and 50. It is most prevalent in Britain, France, Belgium, Germany, European Russia, Austria Hungary, and the United States of America. It is possible, of course, that this distribution is entirely accounted for by the distribution of population, and by the fact that these are the centres of industrialism, which, as will be shown later, apparently engenders the very conditions which call it into being.

* Though most prevalent in the above regions, which in reality lie between latitudes 40 and 50, it is also found in Northern Italy, Northern Spain and Portugal, European Turkey (Constantinople) and Egypt*, all of which lie north of the tropic of Cancer.

* Fischer, *Monchener Jahrbuch*, iv. 4, 1844. Quoted by Koenen, *loc. cit.*

[illegible] small province of Japan (Shiraï*, about latitude 37-38, [illegible] have been described, and on occasional case has been recorded in Lower and Burmah**. Examples have also been met with in Iceland†. In spite of the bad hygienic conditions under which the Esquimaux live, the disease however must be rare, as Sir[illegible] after a fairly extensive search through the diaries and journals of travellers in Iceland, Greenland and Alaska, I have [illegible]

In reply to a personal enquiry of the Alaska School Service, I learned that groups of cases had recently occurred in several of the villages on the Yukon River, north of the Arctic circle. Dr. Neumann had charge of [illegible]. A curious feature about the epidemic is that [illegible] to groups and "that at least half a dozen of the children died." He further [illegible] that "the natives in the villages [illegible] were living under better conditions than in former years" and it was [illegible] what the disease is.

So far as we can gather, only isolated examples of the disease have been observed in [illegible] America, Australia, New Zealand and [illegible]. It seems to be [illegible] rare in China. But in South America [illegible] recorded in Brazil was described by Gonçalves as that the condition is "not uncommon in Brazil," and gives as the vulgarest name "[illegible]." In Peru [illegible] can be given no description of individual cases, but states that the symptoms are the same as those in England. Europe, Germany and North America.

[illegible] personal communication from a foreign resident has come to hand, in which he [illegible] that he had only seen two cases during [illegible] years. In one of the cases the disease developed [illegible] and made a remarkable recovery, when [illegible] milk was given along with the administration of cod liver oil and hypophosphites. Isolated examples like the latter appear to be [illegible] the Argentine Republic and in Australia, and especially when it is recalled that until comparatively recently many physicians still considered scurvy to [illegible] rarely seen in [illegible].

Rickets would seem to be unknown when savage races live under natural conditions, but exceedingly often these people [illegible] dwell in civilized communities, as in New York†† where one family

---

* Osaka Medical and Chemical Society, Osaka 1887

[illegible] Calcutta Med. J., 1886, [illegible] p. 734. † Sumner Walker, Trans. Path. Soc. London, 1881, p. 280.

‡ Dr. Jonsson says [illegible] rickets among people in Iceland, but the [illegible] Journal of Medical and Chirurgical Sciences, Vol. III, p. 139.

§ Dr. Cantlie, M.D., London (personal communication).

¶ Transactions 8th International Medical Congress, 1887, Vol. III, p. 575.

†† Med. Journal of Pathology and Childbirth, 1867, p. 251.

sees a negro child without some evidence of the disease. The same is a striking feature here. I do not recall ever seeing a non rachitic half-caste negro child. It is notorious that these native races in civilised countries inhabit the worst quarters of our towns.

5. Prevalence.

Unfortunately there are no figures which enable us to form any true estimate of the incidence of the disease among the general population of different districts, far less in different countries. Practically all of the statistics published, at least those which I have been able to find, refer to the frequency of the disease as it affects sick children attending hospital clinics. And even in connection with these statistics it has to be borne in mind that different authors have very different standards for diagnosing the disease.

One would have thought that with the exception of the medical examination of school children unfamiliar[1] the nature would have been forthcoming. If, for example, a census made of the presence or absence of rickets in all children at the age of five years on entering school, definite information would be obtained and certainly a most valuable lighty would be available. Unfortunately, however, School Medical Officers combine all cases of rickets for the various ages. By this procedure the percentage incidence of the disease is greatly reduced as children are included who may have had the disease but in whom on account of their age all trace of the mischief has disappeared. The following statistics[2] abstracted from such School Medical Officers' records showing the ridiculously low percentage incidence amply support the truth of this criticism:—

Glasgow	7·0%	Paisley	5·0%
Edinburgh ..	0·8%	Leith	2·3%
Govan Parish ..	5·8%	Greenock ..	4·8%
Dundee ..	4·1%		

McGregor[3] attempted to solve this question by examining all children admitted during a period of 18 months to Belvidere Fever Hospital, Glasgow. He found that between the ages of 6 months and 2 years 42·5 per cent. of the children presented evidence of the disease, whereas of the children between 2 and 10 years of age 31·6 per cent. of the boys and 26·7 per cent. of the girls were affected.

Dick[4] in an examination of the teeth of children in L.C.C. schools in the East End of London found that 30 per cent. showed distinct evidence of rickets. The advantage of the teeth as an index of rickets is that they show long afterwards the effects of defective calcification. In close agreement with these figures

[1] Kerr-Muir, *Defective Children*. London, 1915, p. 168.
[2] McGregor, *Defective Children*, loc. cit., p. 269.
[3] Dick, *Proc. of Roy. Soc. Med., Sec. for Study of Dis.*, 1915, p. 85.

are the results of Schmorl* who found during the post-mortem examination of 386 children under 4 years of age that 345, or 89·4 per cent., presented histological evidence of rickets.

We are hopeful that the Infant and Child Welfare Scheme about to be inaugurated will, among its other advantages, provide us with the necessary information on this question.

The evidence at least shows that the condition is of extremely frequent occurrence, *amounting to probably not less than* 50 ***per cent. of the general population of our industrial areas.***

6. Age Incidence.

Rickets is a disease of late infancy and early childhood—at least it is between the ages of 9 and 24 months that it is most frequently seen. This estimate of the age incidence is based on clinical grounds, but Schmorl† has shown that histologically it is most frequently encountered between the ages of 4 and 18 months.

At one time it was considered that the affection might be congenital, but recent research has completely refuted any such idea. It was with Virchow‡ that the doctrine of congenital rickets arose. He described in 1853 three examples of what he considered foetal rickets. Soon after, however, he recanted from his former opinion, and admitted that in all probability the cases were cretins, but his descriptions and reputation had given a stimulus to the theory of congenital origin, and similar cases were put on record from time to time.

In 1889 Kundberg and Marchand§ described cases similar to those of Virchow, and showed clearly that they were not examples of rickets, but definitely of myxoedema.

Virchow and his successors had confused rickets, achondroplasia and myxoedema, basing their diagnosis chiefly on the presence of osseous deformities and defective development. We now know that the changes in all these conditions are totally different. In achondroplasia there is premature synostosis, in rickets there is hyperplasia of the epiphyseal regions with delay in ossification, and in cretinism, so far as the bones are concerned, there is simply an arrest of growth. It must be remembered that true rickets may complicate cretinism, but as a rule it is late in developing.

More recently Kassowitz‖ resuscitated the idea of the congenital origin of rickets and put the incidence of the disease in the new-born as high as 90 per cent. He was followed by Feer, Marfan and others, but all founded their opinion on clinical

* Schmorl, *Verhandlungen der deut. path. Gesellsch.* 1909, p. 58.

† Schmorl, *Ergeb. d. inn. Med. und Kinderheilk.* Bd. IV, 1909, p. 403.

‡ Virchow, *Virchow's Archiv*, Bd. 5, 1853, pp. 481 and 494.

§ Axel Wyllard, *Ergeb. der Med. und Chir.* Bd. VI, p. 64.

‖ Kassowitz, *Wien. klin. Woch.*, 1888 and 1889. Kassowitz, *Institut für Heilung und Erforschung der Rachitis*, Wien und Leipzig, 1884.

examination alone. An open fontanelle, protuberant abdomen, thickening of the costo-chondral junctions and softness of the bones, especially of the cranium suggesting cranio-tabes, were for them evidence of rickets. With the possible exception of the pseudo-cranio-tabes all the above manifestations are physiological in the new-born, and consequently one is not surprised at the high percentage incidence estimated by Kassowitz. Kassowitz also drew attention to a not infrequent change in the epiphyseal lines of the new-born, but Pommer*, who strongly combated this view of congenital origin, demonstrated that Kassowitz was confusing syphilitic osteochondritis with rickets.

Wieland†, who has recently written extensively on the question of congenital rickets, has shown that although softening of the cranial bones is present in about 20 per cent. of infants, it tends to disappear just at the age at which rickets appears. This author further points out that the parts of the skull affected with "congenital softening" are quite different from those parts attacked by true cranio-tabes. The latter involves chiefly the central portions of the occipital bones, whereas that variety present at birth is found at the margins of the parietal and frontal bones. And, finally, Wieland says that the congenital softening of bones has none of the histological features of true rickets, and in all probability is an anomaly of development.

Schmorl's‡ researches are of great importance in the adjudication of this question. He examined the bones of children under 4 years of age dying between the years of 1901 and 1908 in Dresden Hospital (386 in all), and subjected them to histological examination, which, as previously mentioned, is the only sure way of making a definite diagnosis. In no case did he find evidence of rickets in a child under 2 months of age.

Although it was stated above that rickets is a disease of infancy and early childhood, it may not only relapse in later childhood or adolescence, but it may develop in a previously healthy and non rachitic individual as late as the twentieth year of life. Strictly speaking, the term "Late Rickets," or "Rachitis Tarda," should be retained for the latter examples, but both are usually classified under the one heading. Relapse cases after 4 years are not very uncommon, but the primary cases after that age are undoubtedly rare.

Symptomatically and anatomically this variety (late rickets) of the disease is not different from that occurring during infancy except that, since the growth of the cranial bones is not so active at this period of life, changes in the skull are slight or absent. On account of the absence of a negative balance in the calcium metabolism in examples of late rickets Schabad considers that it is

* Pommer, *Untersuchungen über Osteomalacie und Rachitis*, Leipzig, 1885.

† Wieland, *Ergeb. d. inn. Med. und Kinderheilk.*, Bd. VI, p. 61.

‡ Schmorl, *Ergeb. d. inn. Med. und Kinderheilk.*, Bd. IV, p. 63.

etiologically different from that variety occurring in infancy (p. 35). Pain and difficulty in walking, epiphyseal enlargement, rosary, bending of bones, flaccidity of muscles, are all present, and may be extreme. The accompanying plates (Figs. 1 and 2) show the naked eye appearance and result of X-ray examination of growing ends of the bones in a girl aged 14½ years, who had developed the disease some months previously.

7. Sex Incidence.

Several workers have paid attention to this aspect of the subject, and it would seem from their collected statistics that males are on the whole more susceptible to the disease than females.

Brünnich[1], in Copenhagen, found among 159 rachitic children 108 boys and 55 girls. Ritchie[2], in Manchester, among 210 cases, 128 boys and 91 girls. M'Gregor[3], in Glasgow, among 391 cases, 211 boys and 180 girls. And Miss Ferguson, in the present investigation of 450 rachitic children, found 228 boys and 222 girls.

Kassowitz, in his investigations, found the sexes equally distributed, and Cheadle, in France, on the other hand, among 346 cases found 198 girls and 148 boys.

8. Seasonal Incidence.

It is the experience of those working in and around the purlieus of children's hospitals that the cases of rickets become especially numerous during the spring months of the year, and fall off considerably during the summer. This seasonal incidence has been remarked upon by many authors.

[illegible] working at the relation of dietetic [illegible] which seem to show that rickets continues to [illegible] with [illegible] of fresh air and exercise, and which is more likely to prove during the winter months, when the deficiency of [illegible] sun during the autumn and dying during the following [illegible] incidence of rickets, wherein there is an spring (April to August) and dying in the autumn (or less from October to January). The most severe examples are seen in those children dating [illegible] of one year who were born in spring.

Schmorl has also studied this aspect of the disease in post-mortem material, and has published a most instructive table of his findings, which I have reproduced (Table I).

[1] Brünnich, "Om Engelsk Sygdom," Dansk. Magazin, 1822.

[2] Ritchie, *loc. cit.*

[3] M'Gregor, *loc. cit.*, p. 18.

[4] Schmorl, "Die pathologisch-anatomischen Untersuchungsmethoden," 1908, No. 9, 1907.

[5] Virchow's Archiv für Pathologie und Klinik der Medicin, Bd. IV, 1908, p. 403.

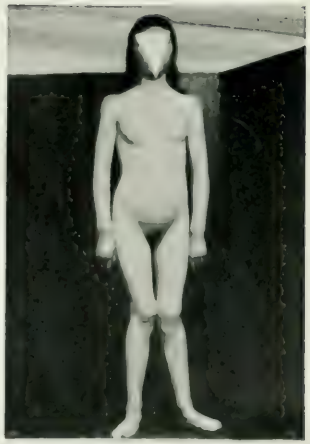


Fig. 1.

M. B., female, aged $11\frac{1}{4}$ years. Case of late rickets, showing rosary, double genu valgum and epiphyseal enlargement at wrists and ankles.

Fig. 2

X-ray photograph of wrist in case of late rickets, showing widening of epiphyseal line and decalcification of lower ends of radius and ulna.

CHART A

SHOWING PERCENTAGE OF CASES EXAMINED (386 IN ALL) WITH ACTIVE AND HEALING RICKETS FOR EACH MONTH OF THE YEAR

COMPILED AFTER SCHMORL

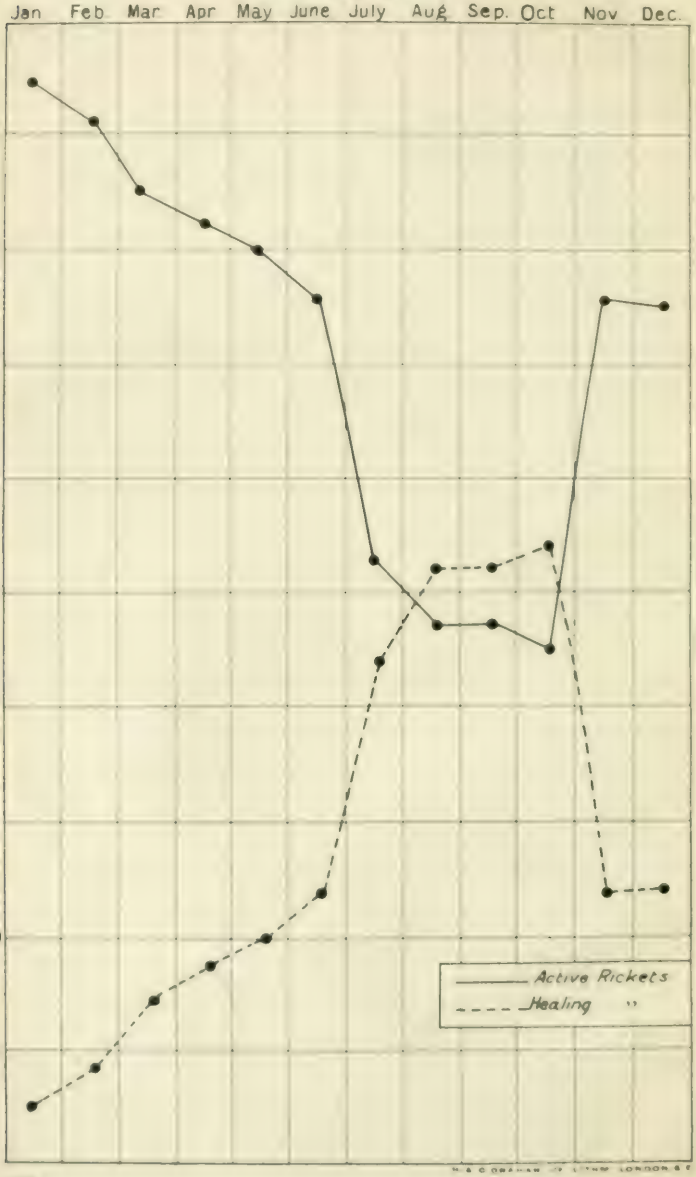


TABLE 1.

	Early rickets.	Advanced rickets.	Healing rickets	Total.
January	7 (35·0%)	12 (60·0%)	1 (5·0%)	20
February	7 (29·2·)	15 (62·5·)	2 (8·3·)	24
March	4 (19·1·)	14 (66·6·)	3 (14·3·)	21
April	3 (17·6·)	11 (64·8·)	3 (17·6·)	17
May	5 (16·7·)	19 (63·3·)	6 (20·0·)	30
June	9 (36·0·)	10 (40·0·)	6 (24·0·)	25
July	6 (23·0·)	8 (30·0·)	12 (44·0·)	26
August	3 (14·3·)	7 (33·3·)	11 (52·4·)	21
September	3 (14·3·)	7 (33·3·)	11 (52·4·)	21
October	3 (13·6·)	7 (31·9·)	12 (54·5·)	22
November	7 (28·0·)	12 (48·0·)	6 (24·0·)	25
December	8 (27·6·)	14 (48·2·)	7 (24·2·)	29

Showing the frequency with which early, advanced and healing rickets was met with at different periods of the year in 386 post-mortem examinations of children under 4 years of age.—Schmorl, *Ergeb. d. inn. Med. und Kinderheilkunde*, Bd. 4, p. 439.

This table shows that although rickets may commence at any time of the year, early and marked cases are most frequent during winter and spring, and least numerous during summer and autumn; whereas cases showing evidence of healing are rare during the early part of the year and most frequent during summer. These points are well exemplified in the accompanying chart representing Schmorl's findings graphically.

9. SYMPTOMS.

Rickets is a disease which is insidious in its onset and chronic in its course. The rate of progress and severity of the condition show wide variations. There is no such disease as acute rickets, all the cases which have been described as such being in reality examples of scurvy, which may attack rachitic as it does non-rachitic infants.

A child which previously had been thriving and developing normally begins to sweat profusely about the head, to be restless at night, and if it had learned to sit or stand to become inclined to do so. It is long in getting teeth—the first tooth may not be cut till after the first year. The anterior fontanelle, which closes in the normal child at about the twelfth to the eighteenth month, remains widely open, and thickening of the growing margins of the bones appears. The parietal and frontal eminences become prominent, and the face seems proportionately small. The costo-chondral junctions become enlarged, and some fulness of the ends of the long bones is apparent. Occasionally, the child seems to be tender and cries when handled. The child generally ceases to increase in weight or emaciates, although in not a few cases obesity is a prominent early feature. It is long in standing and in learning to walk, and the bones of the limbs become bent.

A diagnosis of the condition in the early stages may be exceedingly difficult or not impossible. It can only be made from the slight changes, and these depend not only on the age of the child, but also on the duration of the process.

When fully developed, however, the rachitic posture is most characteristic and can hardly be mistaken for any other condition. The child is apt to sit in bed or on the nurse's lap with the legs crossed and supporting the body with the outstretched arms. The cranium looks large, has a somewhat square shape with overhanging forehead from the development of frontal and parietal bosses. The anterior fontanelle is usually open, with thickened margins. Softening of the cranial portions of the occipital bones—craniotabes—may be present, though in my experience this is not frequent, and is only found in younger patients. At one time craniotabes was considered by many English writers to be syphilitic in nature[1], but I have seen undoubted craniotabes in non-syphilitic rachitic infants. On the Continent so strong is the opinion of the rachitic origin of craniotabes that this change is frequently taken as a gauge of the efficacy of treatment.

In cases over 2 years of age the teeth are usually prematurely carious and may only be represented by a few decayed stumps.

The chest is small and narrow, with lateral depressions, giving it the so-called "bell shape." Beading of the ribs due to enlargement of the costo-chondral junctions is felt, and, if very prominent, may be seen as a string of beads down each side forming the "rickety rosary." In very severe cases acute bending of the ribs in the posterior auxiliary line may occur with swelling, giving rise to the posterior rosary. Occasionally a horizontal depression about the level of the xiphisternum and just above the liver—Harrison's sulcus—is observed. The lateral depressions are due in part to atmospheric pressure and in part to muscular action, whereas the horizontal one is chiefly due to atmospheric pressure.

The abdomen is pot-bellied from atony of the gut and abdominal wall with consequent tympanites and on account of the relative smallness of the thorax, the liver and abdominal contents of the upper region being pushed downwards. The spleen is seldom palpable, and when it is tuberculous, syphilitic or splenic anæmia or some infection can usually be discovered as the cause.

The ends of the long bones are enlarged, especially at the wrists and ankles, and the bones themselves variously distorted. The deformities may be extreme, and result not only from bending, but also from fracture. It should be remembered, too, that the bending does not always depend on whether or not the child has begun to walk, as in many instances marked curvature of the long bones may be present before the child has even made the attempt.

[1] Carpenter, discussion, *Brit. Med. Journ.*, 1868, Vol. VIII, 1868, p. 123.
† Lees and Barlow, *Trans. Path. Soc. London*, 1881, p. 323.

The curvature may implicate both upper and lower limbs, but is usually most severe in the latter. There may be genu varum or genu valgum on either side, or genu varum in one leg and genu valgum in the other.

The spinal column is almost invariably the seat of curvature, most frequently of the nature of kyphosis, which may occasionally be so marked as to suggest Pott's disease. At other times, though more rarely, a greater or less degree of lateral curvature or scoliosis is present.

A striking feature of the disease is the unequal distribution of the bone changes; in one case the legs suffer chiefly, in another the arms, in still another the thorax, and in others again the head; nevertheless, in not a few cases, all parts of the skeleton are equally and severely affected.

The curvatures of the long bones contribute towards the dwarfism of the rachitic skeleton, but arrest of growth in length of the bones themselves is another important factor. The bones chiefly affected in this way are those of the face and the lower limbs, for the simple reason that they grow most rapidly, and thus the persistence of the infantile proportions—the large cranium and proportionally short legs—is produced. This was well shown by Shaw* early in last century, and I have been able to corroborate in the main his findings. During the first $3\frac{1}{2}$ years of life the legs normally increase in length $11\frac{3}{4}$ ins., *i.e.*, by 133 per cent., whereas the arms increase only $6\frac{1}{4}$ ins., representing an increase of 82 per cent., and the body 7 ins., or 70 per cent., so that with arrest of growth those parts which grow most rapidly suffer most, and thus the legs become small proportionately to the arms. This is in marked contrast to the condition in achondroplasia, where both arms and legs are equally affected. During the first six years of life the face bones increase in length by $1\frac{1}{2}$ ins., or 86 per cent., while the circumference of cranium shows an increase of $5\frac{3}{4}$ ins., a percentage increase of only 42 per cent. Shaw held that the head is never increased in size in rickets, and that it only looked large in comparison with the face from arrest of growth of the bones of the latter. Although this would seem to be correct for the majority of cases, examples of increased circumference of the cranium are undoubtedly met with.

Flaccidity of the limbs due to muscular weakness and laxity of the ligaments is very characteristic, so that rachitic children are often spoken of as being double jointed, since it is possible to place the limbs in all sorts of peculiar positions. The heels can be placed in the nape of the neck, and the feet so inverted or everted that the heels point directly upwards. The muscular weakness may be so severe that the child is unable to support itself in either the sitting or standing posture. As a rule, however,

* Shaw, *Medico Chirurg. Trans.* London, Vols. XVII, p. 434, and XXVI, p. 336.

in marked contrast to the paralysis the child can move his limbs quite freely when excitable.

Sore throat and tonsillitis are the chief past characteristic symptoms of rickets and they are the only symptoms on which a diagnosis can be based; but several other manifestations due to visceral changes are associated with these, and will, in consequence, be touched upon.

Rickety children look pale, and many authors (e.g. Moncorvo[1]) hold that in rickets there is a paucity of corpuscles. It would be found, however, that in the vast majority of cases the mucous membranes are of good colour, and I have shown that there is often a slight polycythæmia.[2] Epistaxis[3] is also frequent on there being an increase in the vascular tension.

Symptoms referable to the nervous system are often encountered. Cranial irritability and tetany occur in about 10 per cent. (see page 29).

Owing to the softness of the thoracic wall expansion of the lungs is impeded, and thus bronchitis and pneumonia are frequent. Pulmonary collapse related to the pressure of the adherent heart and collateral emphysema are not infrequently found post-mortem and also dilatation of the right side of the heart, probably in consequence of the resultant obstruction to the pulmonary circulation.

Gastro-intestinal disturbances have been described as characteristic of rickets. That I do not think them so will be pointed out, and will be noted later. Vomiting is another frequent cause of the disease, as mentioned above, but in my experience the majority of cases have a natural digestion, diarrhœa and constipation being the exception rather than the rule. The question is further dealt with in Miss Ferguson's observations (p. 181).

Liver [illegible] have never met with [illegible].

It will be seen from the above review of the general course of rickets that the disease is generally confined chiefly to one of the osseous system. In defining the disease it was looking at it as one of growing bone. Many writers, however, e.g. Jacobi,[4] Cheadle,[5] and Pawlik,[6] dwell on the multiplicity of other tissues and organs affected in cases of general rickets. Jacobi says: "Rickets is not merely a disease of the bones, but affects every one of the tissues of the body."

Undoubtedly changes in the tissues generally do occur, but it may be justifiable to consider that they are secondary in nature

[illegible]

[illegible]

[illegible]

rather than an integral part of the disease. As Holt* says, "The visceral changes are not infrequent, but they are not essential."

The pulmonary and cardiac manifestations are entirely due to pressure and are mechanical in origin; the supposed anæmia does not exist, and the nervous symptoms are probably evidence of tetany, a disease *sui generis*, and probably caused by disease of the parathyroid gland. The various manifestations of tetany (facial phenomenon, laryngismus stridulus, carpopedal spasm and eclampsia) are chiefly observed during childhood in rachitic subjects. In the present investigation tetany was encountered in 40 per cent. of all the cases of active and healed rickets studied, while no undoubted instance of tetany was observed in the non-rachitic children examined (p. 56). So striking is this association of tetany and rickets that many authors, among whom may be mentioned Cheadle and Kassowitz, look upon the conditions as merely different manifestations of the one pathological process. The nervous symptoms do not, however, bear any relationship to the severity of the osseous changes, and marked tetany is found in examples of healed rickets long after the active stage of the disease has disappeared. It is found, too, in infants even as young as two weeks, at which age there can be no question of its being associated with rickets.

It is possible, of course, that there are several varieties of tetany. This I think unlikely so far as childhood is concerned, since it has been shown that in both experimental parathyroidectomy and in tetany in childhood there is one constant and very definite finding, viz., increase of guanidin in the blood and urine†. One might be justified in doubting if such a distinct metabolic change, which can be induced experimentally by parathyroidectomy, could ensue in the human subject apart from disease of the parathyroid glands. Since, however, guanidin is a product of decomposition of protein, it is just possible that this decomposition might take place in the intestine and the guanidin be absorbed. There is, however, no experimental proof of such an occurrence, and large doses of guanidin can be administered to cats (old and young) without toxic symptoms being produced. McCarrison's‡ contention that the changes in the parathyroids are the result of toxic products absorbed from the intestine is not opposed to this view.

MacCallum§ has pointed out the importance of calcium salts in suppressing the symptoms of tetany. It is possible, therefore, that in rickets, where there is a disturbance of calcium metabolism in the direction of a much diminished retention, a hyper-excitable condition of the nervous system is induced, and that the onset

* Holt, *loc. cit.*

† [illegible] *Journal of* [illegible] 1917, X, 414.

‡ McCarrison, *The Lancet*, 1917.

§ MacCallum and Vogt, *Journ. Exp. Med.*, 1913, XVIII, p. 648.

of the symptoms of tetany due to defective parathyroid action and to excessive production of guanidin is favoured. The serious objection to such an assumption is the fact that so far as the deprivation of calcium is concerned the bones alone seem to suffer (p. 37).

Enlargement of the spleen, as pointed out first by Glisson, is not a feature of the disease and recently Cowan and MacClure* and others have conclusively shown that uncomplicated rickets is not accompanied by splenomegaly.

The implication of the muscles is more difficult to dispose of. In many cases the muscular weakness is extreme and seems out of all proportion to the severity of the osseous changes, so much so at times that one is constrained to believe that some myopathic condition is present. Electrical tests of muscles and nerves in rickets give normal readings. It is interesting to note in this connection that tremors of the muscles with weakness is characteristic of tetany.

Heinecke, Heubner and Zappert, in the absence of definite histological changes, are inclined to the view that the weakness of the muscles is secondary to ease induced by pain in the limbs. Hagenbach-Burckhardt and Bingt, on the other hand, believe that it is the seat of a primary and specific dystrophy. Bing bases his opinion on microscopic changes in the muscles. He states that in all severe examples of the disease the muscular fibres are abnormally narrow, the transverse striation obscured, and the nuclei increased in number. Martins§ however, in more recent investigations, cannot corroborate Bing's findings. It may be that it is disease which causes the atrophy and weakness of the muscles, and that in part the paresis is of the nature of a reflex to protect the painful parts against movement; but in view of Bing's researches further work is necessary before a primary implication can be excluded.

D. Pathological Changes.

(1) *Changes in the Bones.*

The bone changes are the essential sign of the disease.

The bone, as a whole, soft, bend easily and cut like cartilage owing to the fact that they contain less calcium than normally. In the normal bone the proportion of organic to inorganic matter is 1 to 3, whereas in rickets this proportion is reversed. According to Langstein and Meyer's chemical examination of a normal and rachitic bone gave the following result :—

	Normal Radius.	Rachitic Radius.
Cartilaginous material ...	29·43%	71·26%
Salts of lime	66·33%	18·26%

* Cowan and MacClure, *Brit. Journ. of Child Dis.*, 1906, p. 343.

† Bing, *Med. Klinik*, 1907, No. 1.

‡ Martins, *Beiträge z. allg. Path. und path. Anat.* Bd. XXI, p. 294.

§ Langstein and Meyer, *Säuglingsernährung und Säuglingsstoffwechsel*, Wiesbaden, p. 202.

FIG. 3

L. to. femur, aged 1½ years. Early rickets. X-ray photograph showing wave contour at lower end of radius.

The bones in rickets are often altered in form, the ends are enlarged, all the sharp edges are rounded off, and they are the seat of curvatures. Sometimes these are simply the exaggeration of the normal curves, and may be due to force exerted by the weight of the body, muscular action, or atmospheric pressure, as, *e.g.*, in the chest. Sometimes the curvatures are the result of fractures which are usually of the green-stick variety. The bones most frequently the seat of fracture are the radius, ulna, clavicle and femur.

The bending of the bones apart from fracture often causes the greatest distortion of the limbs, most marked as a rule in the legs. Here genu valgum, due to curvature of tibia and femur, or genu varum due to curvature of tibia, may be present. There may be genu varum in one leg and genu valgum in the other. At times the curvature is antero posterior, recalling the sabre tibia of congenital syphilis, but in rickets, as X ray examination shows, the bone is simply bent, whereas in syphilis the altered form is due to new formation of bone on its anterior aspect.

The lower limbs may be greatly distorted, and, as in osteogenesis imperfecta, not conform to any of the above types. There is, however, one characteristic feature which, when present, is pathognomic of rickets, viz., the tibial spine or Macewen's tubercle. This osseous spine on the inner aspect of the head of the tibia I have never seen except when the deformity was due to rickets.

X ray examination of bones. By X-ray examination the bone changes are as a rule clearly revealed, and in a doubtful case the diagnosis can usually be settled in this manner. I am unable to say if osseous changes can be shown by X-ray examination in advance of the other clinical symptoms, but there is no doubt that in very slight cases they can be very plainly discerned. I find that the changes are usually best seen at the wrist, though in a few cases the bones have appeared normal at the wrist, while at the ankle joint they have presented rachitic changes. Such variations in the joints affected have already been alluded to.

In rickets the bones seldom show the appearance of a delicate network so characteristic of normal bone. Not infrequently the bone is represented by a homogeneous shadow devoid of all detail. At times, however, the trabecular network is quite apparent, but it is coarser, less regular, and more unevenly distributed than in the normal. This latter appearance is best seen in very young cases, or in those in which the disease has been in existence for a long time.

The changes are most constant and characteristic at the growing ends of the bones. The ends are increased in diameter, and especially is this true of the carpal end of the ulna. They present, too, a variously sized area of diminished density, and have a concave or wavy surface instead of the normally sharply defined flush or slightly convex ends. (Figs. 3 and 4). In older

In rickets the appearance of the centres of ossification of the epiphyses is delayed, and when they are present they are ill defined and smaller and more widely separated from the diaphyses than in health. Occasionally however calcification of the ulnar epiphysis would seem to be premature. At least in two cases of rickets, aged 3 and 7 years respectively (Fig. 3), this centre was quite apparent, whereas in any normal wrist of 7 years that I have examined, no shadow in this situation could be detected. So far as my experience goes the ossification of the carpal bones is always delayed, and the shadows representing these bones are smaller and more widely separated from one another than is normal for the age of the patient.

Microscopic Characters.—On section of any long bone the most striking abnormality is the increase in width of the cartilaginous growing zone. Normally this growing zone is truly a line—the epiphyseal line—forming a narrow, glistening, bluish white band sharply demarcating the diaphysis from the epiphysis. In rickets it is increased in thickness many fold, is irregular, and extends by tongue like processes into the diaphysis. Sometimes these areas of cartilage are completely cut off from the growing epiphyseal zone and, as suggested by Virchow, may form nuclei for the development later of enchondromata. Occasionally this hyperplastic tissue retains the appearance of having been deposited in layers, the one layer being separated from the other by a vascular zone. More frequently, however, no such arrangement is visible, and irregular islands of uncalcified cartilage separated by vascular spaces predominate. These vascular areas give the idea of hæmatoma, and have suggested the view that the condition is inflammatory in nature. The marrow cavity seems unduly wide, and there is the appearance of increased bony tissue under the periosteum.

Microscopic characters.—On microscopic examination the irregularity of the epiphyseal zone is even more striking.

At the growing end of the shaft of any long bone of the normal child the first change observed is a proliferation of the cartilage cells, which subsequently become arranged in rows in the long axis of the bone. The cell spaces enlarge and become confluent forming the primary marrow spaces. The cartilage cells then degenerate, and the spaces are invaded by vessels from the perichondrium accompanied by osteoblasts and connective tissue. The vessels of the perichondrium encircle the bone in rows as hoops do a barrel, and thus the invading vessels are arranged at different levels and give to the bone a somewhat striated appearance (Schmidt and Schmorl).* These branches enter the bone at right angles to the long axis, and mainly in the primary marrow spaces. They do not anastomose, but terminate in end arteries. According to Schmidt* these vessels vary in number in different bones and their relative abundance is a

* Schmorl, *loc. cit.*

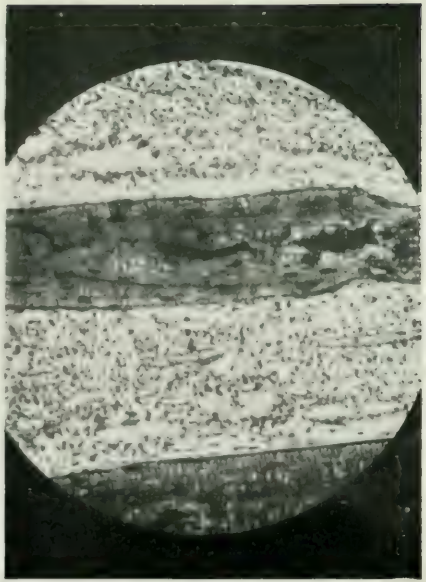


FIG. 5.

Section showing structure of trabeculæ of normal bone. High power.

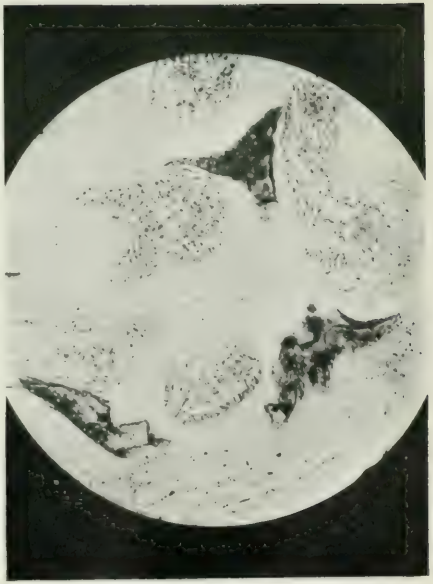


FIG. 6

Section of rachitic bone, showing osteoid tissue (A) and poorly formed and irregularly placed bone cells (B) (experimental rickets). High power.

FIG. 2.

measure of the rate of growth of the bone. The cartilaginous matrix between the cells next becomes calcified, and these pillars of calcified cartilage form a scaffold on which bone is deposited. The normal bony trabeculæ thus formed are occupied for the most part by almost parallel rows of elongated bone cells, with their processes running at right angles to the margin, and are surrounded by a mere rind of homogeneous "osteoid" tissue (Figs. 5).

In rickets there is an excessive preparation for the formation of bone in the greatly increased depth of the layer of proliferating parallel arranged cartilage cells. The disappearance of the cells is delayed, and occurs erratically, so that irregular areas of cartilage remain as such, and are neither absorbed nor infiltrated with lime. These tongue like processes of cartilage alternate with areas of partially or almost normally calcified tissue, with an apparent increase of the intervening marrow. When ossification occurs it takes place irregularly. The trabeculæ persist for the most part, however, as homogeneous processes with or without ghosts of cartilage cells—the so-called osteoid tissue—with small central zones occupied by dwarfed and irregularly placed bone cells (Fig. 6).

It is the development of this osteoid tissue that is the true characteristic histological feature of rickets.

There has been a good deal of discussion as to whether or not there is excessive production of tissue at the growing ends of the bones. Most writers are of opinion that such does take place, and certainly the clinical and unequivocal swelling of these parts supports such a view. Schmorl*, however, holds that there is no increased formation, and that the appearance of such having taken place results from an deficient absorption of cartilage, which undoubtedly is a feature of the disease. Although it would seem to me impossible entirely to prove or disprove such a line of argument it is unlikely that there is no increased formation, as the degree of enlargement of the epiphyses greatly depends on the influence of outside forces, as strain. The costo chondral enlargement is most marked on those ribs which move most freely, and that at the ankles is most marked in those children who have attempted to walk. In one of experimental rickets in the dog I have seen the typical bony changes in the bones of all the limbs except one which was the seat of fracture of the femur (Fig. 7)

Bone marrow.—As mentioned above the marrow in rachitic bones seems unduly abundant and according to Pommer†, is hyperplastic in nature. Pommer states that microscopic examination reveals an excessively cellular tissue, with in places an increase in number and size of capillaries and occasional deposits of pigment, with at times an increase of the connective tissue. He says very definitely that there is never an excessive

* Schmorl, *loc. cit.*

† Pommer, *loc. cit.*

amount of fat but in my cases of experimental rickets the only change that I could detect was an increase in the amount of fat. The marrow in infancy and childhood is always hyperplastic, and thus Brian concludes that in rickets the marrow shows little change from the normal. Children rarely die from rickets, but as a rule in consequence of some acute inflammatory complication which of itself tends to cause a hyperplasia of the marrow so that in view of these physiological and pathological considerations the whole question of the changes in the marrow in rickets seems worthy of reinvestigation.

The nature of the change in the bones.—Schmorl, Pommer and Schmidt all see the primary change in the disease as deficient calcification of the cartilage and ask the question, "Why does the rachitic tissue remain uncalcified?" It is these writers who are responsible for diverting much of the attention in recent years to this one aspect of the problem, viz., calcium metabolism.

(a) *Calcium Metabolism*

Calcium metabolism in health.—From a *resumé* by Ongler* of the work done previous to 1912, the following results are abstracted.

TABLE 2.

Table showing Average Daily Retention of CaO in Health and in Rickets (after Ongler).

Number of Cases Investigated	Age of Children	Diet of Children	Max. Retention in Grms. CaO	Min. Retention in Grms. CaO	Average daily Retention in Grms. CaO	
9	14 days	Healthy	Breast Milk	+ 209	+ 042	+ 124	
6	1 week	,,	,,	+ 180	+ 034	+ 149	
6	2½ weeks	,,	Cows Milk	+ 412	+ 159	+ 221	
7	6 [illegible]	,,	,,	+ 295	+ 034	+ 253	
5	4–11 weeks	Rickets	,,	+ 339	+ 045	+ 117	Average daily Retention in 13 cases = + 074 grms.
8	4–11 weeks	,,	,,	+ 262	+ 093	+ 118	
9	1–5 years	,,	,,	+ 307	+ 035	+ 284	Average daily Retention in 11 cases = + 166 grms.
7	1–11 [illegible]	,,	,,	+ 481	+ 267	+ 374	
6	11 weeks	,,	Cows Milk	+ 146	+ 071	+ 109	Average daily Retention in 5 cases = + 092 grms.
5	11–18 years	,,	,,	− 098	− 064	− 081	

From an examination of the above figures it is seen in the first place that in health the calcium retention varies within very wide limits but that generally it increases with age, and

* Ongler: *Ergeb. der inneren Medic. und Kinderheilkunde* Vol VIII, 1912 p. 132.

that although the absolute retention is greater in artificially than breast fed infants, the percentage absorption is found to be less.

In 9 normal breast-fed infants of less than 14 days the average daily retention of Ca estimated as CaO was 0·121 grms., with a maximum of 0·209 grms. and a minimum of 0·042 grms. In 6 healthy breast fed infants between 1 and 5 months of age the average daily retention of CaO amounted to 0·149 grms., the maximum being 0·183 grms. and the minimum 0·054 grms. In 6 healthy artificially-fed children between 2½ and 5½ months the average daily retention was 0·221 grms., with a maximum of 0·412 grms. and a minimum of 0·120 grms., and in 9 artificially-fed children between the ages of 6 and 10½ months the average daily retention of CaO was 0·253 grms., the maximum being 0·925 grms. and the minimum 0·054 grms.

In illustration of the greater retention of the salt on a diet of cows' milk than on one of human milk, the following figures compiled from several experiments by Langstein and Meyer* may be quoted :—

Diet.	CaO Intake.	CaO output.		CaO retention.	
		Urine	Fæces	Absolute.	%
Breast milk . .	·2884 g.	·0127 g.	·0952 g.	·176 g.	+ 62·44
Cows' milk ...	2·0824 g.	·0166 g.	1·142 g.	·924 g.	+ 44·4

It has been suggested by Dibbelt† that the increased retention with cows' milk is directly related to its greater calcium content, and Kochmann and Petzsch‡ conclude from animal experiments that by the administration of certain salts of calcium the amount retained can be increased. Orgler§, however, who has carried out experiments in the child on the administration of calcium salts did not find that the amount retained could be so influenced.

That the behaviour of the calcium retention is probably much more closely related to other elements in the diet, *e.g.*, fat, is suggested by the work of several observers. The following experiments with diets poor and rich in milk fat seem to show that increase of fat causes a fall in the amount of calcium retained.

* Langstein and Meyer, *Säuglingsernährung und Säuglingsstoffwechsel*, Wiesbaden, 1910, p. 17.

† Dibbelt, *Der Phosphorgehalt der Kuhmilch*, *Arbeiten a.d. path. Institut in Tübingen*, Bd. IV., 1908, p. 670.

‡ Kochmann and Petzsch, *Biochem. Zeit.*, Bd. XXXII, p. 10.

§ Orgler, *Monat. f. Kkde.*, No. 10, p. 373, 1911.

(1) Rotlberg (*Jahrb. f. Kinderheilkunde*. Bd. LXVI. 1907. p. 69.)

Duration of experiment. 3 days with each diet.

CaO	Skim Milk	Cream 1 part Water 2 parts
Intake	925 grms.	927 grms.
Output in urine ..	020 ..	0 ..
Output in faeces	818 ..	1 125 ..
Amount retained	+ 0·137 grms. p.d.	− 0·198 grms. p.d.

In this experiment the question of a diminished protein intake must be considered.

(2) Stenitz (*Jahrbuch f. Kinderheilkunde*. Bd. LVII. 1903. p. 689.)

Duration of experiment	4 days	3 days
CaO	½ Milk + 8% Fat	½ Cream (5·28% Fat)
Intake	398 grms.	378 grms.
Output in urine	005 ..	0 ..
Output in faeces	485 ..	472 ..
Amount retained	+ 0·08 grms. p.d.	− 0·44 grms. p.d.

(3) Meyer (*Biochem. Zeitsch.* Vol. XII, p. 422. 1908.)

Age of child. 3 months.

Duration of experiment. 3 days on each diet.

CaO	½ Milk + 16 grms. Casein	The same + 20 grms. washed Butter Fat
Intake	254 grms.	219 grms.
Output in urine	004 ..	003 ..
Output in faeces	218 ..	197 ..
Amount retained	032 grms. p.d.	+ 019 grms. p.d.

(4) Meyer (*Biochem. Zeit.*, Vol. XII. 1908).

CaO	Milk 21 grms. Cream	The same 25 grms. washed Liver Fat
Duration of experiment	3 days	4 days
Intake	421 grms.	427 grms.
Output in urine	"	0 "
Output in fæces ...	·470 "	·547 "
Amount retained	[illegible] p.d.	120 grms. p.d.

(5) Ongley (*Edinb. Journ. Med. and Chir.*, Ed. VIII. p. 170).

CaO	½ Milk and Barley Water	Whole Milk
Intake	770 grms.	1·285 grms.
Output in urine	011 "	0·024 "
Output in fæces	722 "	1·528 "
Amount retained	+ 0·037 grms. p.d.	− 0·267 grms. p.d.

All varieties of fat, however, do not appear to produce this effect. Cod liver oil and Sesame oil were found to cause an increased retention of calcium, as the following experiments show. It is possible that this may explain the beneficial effect of cod liver oil in rickets. Its prophylactic action has recently been maintained by Hess and Unger in communities of negro children in New York.*

(6) Ongley (*Biochem. Zeit.*, Bd. XVI. 1907, p. 455).

Duration of experiment 6 days each period.

CaO	Milk and Bread	The same + Cod Liver Oil
Intake	1·404 grms.	1·672 grms.
Output in urine	0·0	0·0
Output in fæces	1·387	0·867
Amount retained	+ 0·116 grms. p.d.	+ 0·465 grms. p.d.

* Hess and Unger, *Journ. Am. Med. Assoc.*, New York, July, 1917, p. 1883.

[7. Freund, *Biochem. Zeit.*, Bd. XVI. 1907, p. 471.]

Duration of experiment	3 days.	4 days.
Salt	$\frac{1}{2}$ Mol.	$\frac{1}{2}$ Mol. + Sodium Oleate
Intake	0·652 grms.	0·716 grms.
Output in urine	0·024 "	0·041 "
Output in faeces	0·586 "	0·431 "
Amount retained	0·041 grms. p.d.	0·254 grms. p.d.

It is impossible to say how the other elements in the diet viz., proteins and carbohydrates act so as to satisfactory metabolism. Experiments with a constant fat content and varying albumen and carbohydrate contents are available. The whole question of the influence of these proximate principles of the food on the calcium metabolism requires further investigation.

Of other factors which influence the calcium retention the most important is exercise. Kochmann and Petzsch*, during the course of a research into the factors influencing calcium metabolism, encountered one animal in which they found it impossible to bring about an increased excretion of the salt. They state in the protocol dealing with this experiment that the animal was never at rest, and they concluded that exercise influenced the retention of the salt.

It is thus seen that in assessing the value of metabolism experiments in rickets several important factors, viz. age, diet and exercise, which of themselves may influence the retention of calcium, must be borne in mind.

Calcium metabolism in rickets.—Since, however, in rickets the bones are deficient in calcium, and since the bones are the chief depots of the salt, it would be surprising if in this disease the assimilation of calcium were not disturbed. As a matter of fact, such a disturbance is not infrequent.

In Ogden's monograph, details of several such examinations are given. Of 13 rachitic children between 4 and 11 months of age, 5 excreted more calcium than they ingested with the food, the amount varying between 0·339 and 0·045 grms. of CaO per diem. In the other 8 there was a retention of the salt varying between 0·097 and 0·262 grms., with a daily average of 0·118 grms., which contrasts with the average daily retention of 0·262 grms. for non-rachitic children of the same age.

Of 5 examples of rickets in breast-fed children between the ages of 11 and 18 months 2 show a loss of calcium amounting to

* L. Kochmann and Petzsch, *loc. cit.*

0·098 and 0·064 grms. per diem, while 3 had an average retention of 0·1 grm., with a maximum of 0·146 and minimum of 0·061 grm. per diem.

Of 11 artificially-fed rachitic children between 1 and 2½ years 2 (1½ and 1½ years old respectively) showed a greater excretion than ingestion to the extent of 0·267 and 0·481 grms. per diem, whereas in 9 the average daily retention was 0·284 grms. of CaO with a maximum of 0·707 grms. and a minimum of 0·037 grms. The greater average retention in the older children and the less frequent loss is in accordance with the observation in normal children, and interesting in view of the absence of Ca depletion in the few available records of similar investigations in cases of late rickets. Schabad* takes this latter finding as evidence that the late variety of the disease is different from that found in infancy. But even in infants suffering from apparently active rickets a loss of calcium is not invariable, and the variations in the amount retained are great. The following records show how under identical conditions and with the same diet a case may present at one time a loss and at another time a slight retention.

(8) Schabad (quoted by Freund, *loc. cit.*).

CaO.	1st.	2nd
Intake	1·4039 grms.	1·2608 grms
Output in urine	0·0 ,,	0·0 ,,
Output in fæces	1·3367 ,,	1·3887 ,,
Amount retained	+ ·0673 grms.	− 0·1274 grms.

(9) Towles (*Zeit. f. Kinderheilkunde*, Bd. I, p. 346).

Duration of experiment, 4 days each period.

CaO	1st	2nd.
Intake	3·1335 grms	4·1216 grms
Output in urine	·005 grms	·0043 grms
Output in fæces	3·2185 ,,	3·0126 ,,
Amount retained	− 0·0170 grms.	− 0·1047 ,,

* Schabad, *Mitt. a. d. Gren. gebiet d. Med. und Chirurg.*, 23, 82, 1911.

(10) 1916-17. [*Marsh and* S *whose* 11th October 1910, p. 2121).

[illegible] of experiment	8 days	5 days
	CaO	2nd
Intake	1·107 grms.	1·583 grms.
[illegible]	1·449	7385
Amount retained	[illegible]	+ 7585 grms. p.d.

In [illegible] a chronic disease as rickets one part of the skeleton may be recovering while another portion is being attacked and as retrogression and progression of the disease are anticipated by increased or lessened retention of calcium Orgler sees a sufficient explanation for the variations In support of this he records the case of a breast-fed child who presented at 1½ months a loss of calcium but no clinical manifestations of rickets till the age of 4 months at the age of 2½ and 4½ months examination revealed a retention, though slight of the salt amounting at these two periods to ·079 grms. and ·071 grms. of CaO per diem respectively.

Calcium content of blood — Aschenheim's[1] work on the calcium content of the blood of normal and rachitic children has been claimed to lend support to Orgler's view He found that in the normal child there was a fairly constant value for CaO of 8 to 10 mgs. per 100 c.c., whereas in rickets it varied between 3·7 and 12·8 mgs. per 100 c.c. Lyman[2] in a similar research using the nephalometer, found 6·6 mgs. Ca = 9·2 mgs. CaO per 100 c.c. of blood as the average of 11 healthy adults Marriott and Howlands[3] on the other hand in the blood of 6 normal infants and 3 adults found a calcium content of 9·8 to 11·3 mgs. per 100 c.c., and in the case of 11 rachitic infants a slightly reduced content which however never fell below 9 mgs., and in 5 of the cases was above 10 mgs. of CaO per 100 c.c.

Calcium content of muscle — Aschenheim and Kaumheimer[4] report that they found a diminution in the calcium content of muscle in rickets in comparison with that met with in healthy

[1] Birk and Orgler, *Monatschrift für Kinderheilkunde*, Bd. IX. p. 513 [illegible]

[2] Aschenheim, *Jahrbuch f. Kinderheilkunde*, Bd. LXXIX. p. 446 (1914

[3] [illegible] *Biol. Chem.*, Vol. XXX. No. 1, p. 1.

[4] Marriott and Howland, *Trans. Amer. Ped. Soc.*, Vol. XXVIII. p. 109 (1916

[5] Aschenheim and Kaumheimer, *Zeitschrift f. Kinderheilkunde*, Bd. X., 1914, p. 456

but Orgler[1], on the evidence of the work of Stoeltzner, Aron and Brubacher, concludes that the calcium deprivation in rickets does not implicate the muscle and is limited to the bone.

Discussion of calcium metabolism. Though it would seem from the above-quoted figures that the calcium retention in rickets is below normal, and that in some cases in very young children there may even be a loss of calcium, the *whole question of calcium metabolism both in health and disease requires revision.* The periods for the most part consisted of 3 days, occasionally 4 days, and very seldom 6 or 8 days. In a recent study (see Table 3) of this question we have found the variations, chiefly due to the great differences in the quantity of fæces passed from day to day, are so great over short periods of 3 days that we consider it is necessary for the patient to be kept on the diet for some days previous to the metabolism experiment, and for the calcium balance to be determined over a period of 7 days. Further results upon this question will shortly be published.

TABLE 3

Showing daily percentage retention or loss of calcium as CaO in examinations made at the Physiology Department, Glasgow University, under our supervision.

Case.	1st day	2nd day	3rd day
Tetany and rickets ...	- 63·8%	- 3·8%	+ 2·6%
Tetany	+ 53·8%	- 68 %	- 78·5%
Tetany	+ 46·1%	- 12·8%	+ 12·0%
Tetany and rickets ...	+ 19·9%	- 26·2%	+ 34·7%
Tetany	+ 61 %	93 %	
Tetany and rickets ...	25 %	2·5%	- 41·7%

Generally the second and third days show more uniform results than the first and second days.

Voit[2] held that rapidly growing dogs of large breeds can be made rachitic by feeding with a diet poor in calcium, and Dibbelt and also Schabad still hold this view of the origin of rickets. As previously mentioned Dibbelt considers mother's milk unable to cover the child's needs for calcium, and thus he explains the occurrence of rickets in breast-fed children.

Stoeltzner has repeated feeding experiments on a calcium-poor diet and has controlled them by histological examination of the bones. By feeding an animal on such a diet soft bones poor in calcium are undoubtedly produced, but examination reveals no increased formation of osteoid tissue which is the one pathognomonic feature of rickets. The bony trabeculæ are narrowed and more widely separated, but otherwise of

[1] Orgler, *loc. cit.*, p. 151.
[2] Voit, *Zeit. f. Biologie* XVI. p. 55.

normal appearance. Further, on a calcium-poor diet the bones generally suffer in the deprivation of the salt, whereas in rickets, at least according to most observers, the diminution of the calcium is chiefly restricted to the bones.

Deficient absorption of calcium from the intestine as the cause of rickets is also excluded by these observations. It might be, of course, that owing to some peculiarity of the gastro-intestinal contents calcium was either prevented from passing to or even abstracted from the tissues. It has already been shown that a diet rich in milk fats probably influences adversely the calcium retention. Under this condition the salt is chiefly excreted in the form of a soap, and it has been suggested that in this way the loss of calcium could be explained. Givens* states that poor utilisation of fats or fatty acids may increase the excretion of lime, but this conclusion is not borne out by his figures. Meyer† however, has shown that the calcium excreted is in excess of that necessary to combine with the fatty acids present; and Freund‡ has demonstrated that soaps can be increased in the fæces without any change in the calcium retention resulting. As a rule calcium is excreted in the fæces as phosphate, and in the presence of fats it combines in part with the fatty acids instead of with the phosphoric acid.

If more calcium is excreted than is ingested, the excess must be derived from previously calcified bone, since bone is the tissue chiefly affected in the deprivation of calcium. This may very well occur through the absorption of old and fully calcified bone which is constantly going on, and the formation of osteoid or rachitic tissue. Two processes are involved: the softening of already formed bone and the failure of the epiphyseal cartilage to fix calcium. On the latter point some interesting observations by Wells§ are worthy of attention. He found that cartilage which normally ossifies, i.e., epiphyseal cartilage, in contrast to cartilage which does not normally ossify, e.g., costal and tracheal cartilage, even after sterilisation by heat, on being introduced into the peritoneal cavity of the rabbit, presents a great affinity for calcium. All tissues under these conditions absorb calcium, but epiphyseal cartilage in a matter of 10 to 12 weeks absorbs almost as much as if it had developed into true bone. Whether or not rachitic cartilage in such experiments will be found to have lost this power of fixing cartilage remains to be seen, but in some few experiments of this nature which we have conducted rachitic cartilage seems to absorb as much calcium as non-rachitic cartilage.

* Givens, *Journ. of Biol. Chem.* Vol. XXXI. No. 2, p. 441.

† Meyer, *Zeitsch. f. Kinderheilkunde*, Bd. 11, 1916.

‡ Freund, *Zeitsch. für innere Medizin und Kinderheilkunde*, Bd. III, 1909, p. 139.

§ Wells, *Journal of Medical Research*, Vol. XIV. (1905-1906), p. 191.

(iii) *Conclusions.*

In rickets, then, all we can say at present is that there exists (*a*) hyperplasia of cartilage, (*b*) deficient absorption of that tissue with imperfect calcification, and (*c*) defective formation of bone; in short, an abnormality of the whole process of ossification. To narrow the question down to one of calcification as has been done by many workers (Schmorl[*], Pommer[†] and Lehnerdt[‡]) would seem quite unwarranted. To what extent muscle and other tissues may be implicated requires further investigation.

II. Etiology.

Many theories have been advanced to account for the etiology, one set considering the disease hereditary in nature, another ascribing the onset of the condition to dietetic errors, still another to defective hygienic conditions, a fourth to changes in some of the internal secretions, and a fifth to microbial or other infection.

(i) *Heredity*

Siegert[§] sees in hereditary predisposition the chief cause of the disease. From an extensive investigation of family histories he concludes that children belonging to the same social class develop rickets or not according to whether the parents had been or had not been rachitic. He holds that the disease is more severe when both parents have been affected, and it is by the influence of heredity that he accounts for the disease in breast-fed children which, as noted below, he considers seldom affected.

As Stoeltzner remarks, rickets is such a widely spread disease that it is not surprising that a history of the disease can often be obtained in the parents. One might also on the same lines make out a case for scarlet fever or measles being hereditary. Cheadle holds that rachitic parentage is of little importance and the present investigation confirms this opinion (p. 59).

(ii) *Dietetic Errors.*

Errors in suckling.—It has been maintained that the want of breast-feeding or its too short duration is a cause of the condition. Siegert[‖] found that out of 845 artificially fed infants 81 per cent. developed rickets, while in 923 infants who had been nourished at the breast for at least 4½ months only 31·5 per cent. became rachitic. On the other hand Holt[¶] mentions that although negro

[*] Schmorl, *loc. cit.*

[†] Pommer. *Untersuchungen über Osteomalacie und Rachitis*, Leipzig, 1885.

[‡] Lehnerdt, *Ergeb. der inneren Medic. und Kinderheilkunde*, Bd. VI, 1910, p. 120.

[§] Siegert, *Verhandl. d. Gesell. f. Khde. Kassel*, 1903. *Jahrb. f. Khde.*, Bd. LVIII and LIX.

[‖] Siegert, *Munch. med. Woch.*, 1905, p. 622.

[¶] Holt, *loc. cit.*

and Italian children in New York are entirely breast-fed they are exceedingly prone to the disease. This question is dealt with in the present investigation (p. 70).

Again, Dodd[1] says that the cases of rickets occurring in children which have been suckled is due to an abnormally low calcium content of the milk; but although he suggests that the calcium content of human milk is lower than that of cows' milk, it has been shown that deprivation of calcium salts causes changes to occur different to those characteristic of rickets (p. 37).

It has been suggested that too prolonged suckling is a cause of the condition. But the Japanese suckle their children for sometimes as long as two or three years, and the disease is rare in Japan. The "fatty" which takes place in the milk a prolonged lactation is chiefly a decrease in the protein constituents with little or no alteration in the fat.

Excess in artificial feeding.—In the artificially fed child almost every possible quality and combination of the different foodstuffs has been accused of causing the disease. Some have maintained that it is consequent on deficiency of proteid, others on an excess of carbohydrate, but perhaps the majority ascribe the disease to a deficiency of fat with or without an excess of carbohydrate. According to Holt* and Chapple† it is due to a deficiency of fat with an excessive amount of carbohydrate; while Bland Sutton‡ has adduced evidence that it is due to deficiency of fat alone. His experiments in the London Zoological Gardens with lion cubs have given great support to the fat deficiency theory, and are so well known that they do not require recapitulation.

Against the idea that the disease is due to a deficiency of fat is the work of Freund and others previously mentioned (p. 37) which tends to show at least that an excess of milk fat causes rather an increased excretion than an increased absorption of calcium. Beerenberg§ has reported the case of a child developing rickets on a high fat diet. It is unlikely, too, that the child should deposit fat, as many rachitic children do, if this element were lacking in the diet or were imperfectly absorbed. It is possible of course that the child is unable to metabolise the fat and simply stores it, or the fat might be derived from an excess of carbohydrate in the diet. Marantic children, however, seldom develop rickets. This question is dealt with in the present investigation (p. 66).

Ashby‖ also supporting the theory that a low percentage of fat in the proteid plays a part, considers that it is not impossible

* [illegible] loc. cit.

† [illegible] loc. cit.

‡ Bland Sutton, quoted by Osmond Rutherford, *Lancet*, Nov. 11, 1911, p. 1258.

§ [illegible] p. 305.

‖ Ashby, *Text-book of Medicine*, Vol. I, p. 406.

that fermentation of carbohydrate may produce toxins which are responsible for at least some of the symptoms of the disease. Heitzmann* considers that lactic acid is the baneful product, and claims to have induced the disease experimentally by its administration. He believes that lactic acid results from fermentation of the carbohydrate and irritates the ossifying tissue. Later workers, however, have not been able to confirm his findings, and our present knowledge of the metabolism of lactic acid renders it untenable.

Esser† held that rickets is due to overfeeding, and based his theory on the similarity of the blood picture in rickets and chronic overfeeding. He contends that chronic overfeeding causes a chronic gastro-enteritis with impaired absorption of the food constituents. Pritchard‡ has recently resuscitated the idea of overfeeding, but believes, like Ashby and Heitzmann, that it acts from excessive absorption with deficient utilisation and oxidation, with the formation of by-products and acidosis and consequent decalcification. The changes in the bones he sees as an attempt to produce excessive oxygen carriers to compensate for hæmolysis, which he states is a constant result of acidosis. Opposed to such a theory is the fact that the decalcification is limited to the bones and that it is not evident in other forms of acidosis. This theory approaches those of an intoxication.

(iii) *Defective Hygienic Conditions.*

Defective hygiene is acknowledged by most authorities to play some part in the etiology of rickets. Confinement with deficient oxygenation has been considered an important factor in the etiology by several writers, for example, Dudgeon§, Clement Lucas¶ and Esser.¶ Kassowitz** is of opinion that it is the breathing of noxious gases consequent on confinement in badly ventilated rooms which is the etiological factor. Von Hansemann†† ascribes the disease to domestication, and under this term he includes all the evil influences of civilisation in contrast to those which would obtain if an individual were living under normal conditions. In support of his contention he refers to the difficulty of rearing animals free of rickets in zoological gardens, and he mentions that monkeys kept in confinement in Japan, where rickets is rare, develop the disease. It will be recollected that in the chapter (p. 12) on the history of the disease the finding of rickets in a monkey confined in one of the Theban temples of ancient Egypt by Lesser has been referred to.

* Heitzmann, quoted by Cheadle, *loc. cit.*
† Esser, *Münch. Med. Woch.*, 1907, p. 818.
‡ Pritchard, *Clinical Journal*, Sept. 13, 1911, p. 365.
§ Dudgeon, *Rep. of the Sec. to the State of Lic. in Ceylon*, Vol. VIII, p. 56.
¶ Clement Lucas, *Brit. Journ. of Child. Dis.*, Feb. 1908.
¶ Esser, *loc. cit.*
** Kassowitz, *Die Pathogenese der Rachitis*, Wien, 1885.
†† Hansemann, *Berlin. klin. Woch.*, 1906, Nos. 20 and 21.

I have therefore adduced evidence that it is through deficient exercise that confinement chiefly acts. I* have published results of experiments upon pups in which this was the only abnormal factor, and in which bone changes histologically identical with human spontaneous rickets developed. These animals were allowed a normal diet, a diet identical to that of the controls, so that any defect of diet was not the causal factor in the development of the condition. They were kept in the same room as the controls, which were allowed exercise, so that presumably they breathed the same air. In exactly what manner deficient exercise induces rickets it is at present impossible to say. It may be that it hinders utilisation of the food, and favours the production of waste products, but of this there is as yet neither clinical nor experimental proof. In view of these results one cannot but regard with suspicion the experimental findings of many workers, and they focus attention on the necessity of providing facilities for exercise in all future experiments on the production of rickets.

To judge from the distribution of the disease climate would seem to exert a powerful influence; but, as previously suggested, it may be that it is simply a question of the distribution of industrialism and the bad housing and hygienic conditions of life associated therewith.

(iv) *Alteration in some Internal Secretion.*

Within recent years the idea that the disease owes its origin to the absence of some internal secretion has been much discussed. It is quite possible that some internal secretion is necessary for the proper development and calcification of growing bone; but there is no experimental proof in favour of such an idea unless we look upon Wells' work as of this nature (see p. 38). Stolzner† suggested that the disease is due to a deficient amount of adrenalin, and states that good results were obtained by its administration; but subsequent workers have not confirmed his conclusions. More recently Basch‡, Mattis, and Klose and Vogt have stated that disease of the thymus gland was the etiological factor, but Renton and Robertson§, in a fairly extensive series of experiments, have not found that thymusless animals are more prone to rickets than normal animals, and I have seen children in whom the thymus, or at least a large part of it, has been removed, develop normally.

* *Brit. Med. Journ.*, July 9th, 1908.

† [illegible] *Kinderheilkunde*, Band LI, S. LIII.

‡ [illegible] *Archiv für Kinderheilkunde*, Bd. LXIV, 1915, S. 289.

§ [illegible] *Arch. of the Med. and Kinderheilkunde*, Bd. X, 1913, p. [illegible]; Klose and Vogt, *Beiträge zur Klinischen Chirurgie*, Bd. LXXIX, 1912.

¶ [illegible] *Journ. of Hygiene*, Vol. XIV, 1914.

(v) *Microbial or other Intoxication.*

The infective theory has been mooted by many. Torune and Salvatore Forte* believe that they have induced the disease in rabbits by inoculating them with watery and alcoholic extracts of the fæces of children suffering from rickets and diarrhœa. Curiously, although rachitic changes are said to follow on injection of either the alcoholic or watery extract, a mixture of the two extracts was found to be quite inactive. Moussu† is also of opinion that rickets is an infectious disease, as he caused a healthy animal to take rickets by confining it in a cage along with a rachitic one; and then, without subsequent disinfection, he confined another healthy animal in the cage, and it in turn succumbed to the disease. Since all dogs kept in cages are prone to rickets, his evidence does not seem strong. Koch‡, as a result of experiments, holds that the disease is due to a mild infection of the growing ends of the bones with streptococci, staphylococci, pneumococci and *Bacillus pyogenes*, and states§ that he has been able to isolate these organisms from the epiphyses of children in the first year of life recovering from infectious diseases. In many of these cases the costochondral junctions showed early rachitic changes. Mircoli‖ states that he has been able experimentally by the injection of pyogenic organisms to call forth in cartilage changes similar to those met with in rickets. Marfan¶ maintains that it is due to autointoxication from the alimentary tract, and states that the gastro intestinal tract is seldom normal in rickets.

Syphilis, it need only be mentioned in conclusion, was at one time considered as a cause of the disease. Parrot** looked upon rickets as practically a manifestation of congenital syphilis; and Moncorvo††, who states that rickets is of frequent occurrence in Argentine, holds congenital syphilis responsible. That syphilis may predispose to the disease and accentuate the osseous deformities, especially of the cranium, is possible; but few, if any, of the writers of to day would uphold Parrot's doctrine.

(vii) *General Consideration.*

The foregoing *resumé* shows that in spite of most varied and extensive research we have practically no real knowledge of the nature or causation of this widespread malady or of the factors which determine its onset.

* Tor and Salvatore Forte. *La Pediatria*, September, 1907.

† Moussu, *Bulletin de la Societ. Centr.*, Vol. LVII.

‡ Koch, *Zeit. f. Hyg. und Infektions-krankheiten*, 72, H. 2, p. 323.

§ Koch, *Zeit. f. Hyg. und Infektions-krankheiten*, 69, p. 436.

‖ Pathologica, 3, p. 562 and 566, 1911.

¶ Marfan, *Le Rachitisme et sa Pathogenie*, Paris, 1911.

** Parrot, Cheadle, *loc. cit.*

†† Moncorvo, *loc. cit.*

that it is a disease of early life and that it is associated with poverty and overcrowding are, of course, established facts, but how these conditions act has never been clearly demonstrated, and the object of the present investigation is to elucidate the part played by heredity, parental care, general hygiene and diet in determining the development of rickets. These had already been partially investigated by one of us (Findlay), but not in sufficient detail, nor had the various conditions always been compared in the rachitic and non-rachitic child of the same social class.

II. A STUDY OF THE SOCIAL AND ECONOMIC FACTORS IN THE CAUSATION OF RICKETS.

By Margaret Ferguson.

1. Object, Methods and Material.

The object of the present investigation is to amplify and extend the observations recorded by Findlay[1] in 1915 on the general hygienic conditions of rachitic children, in order to throw additional light on the influence of those factors in the production of the disease.

In his investigation the points studied were

1. The length of time the child was breast fed.
2. The order of the child in the family.
3. The condition of the bowels previous to the onset of the disease.
4. The amount of air space in the house allowed to the child.
5. The number of stairs up that the house is situated.
6. Whether or not the child had been taken much out of doors.

Except on points 1 and 5 these studies were confined to rachitic families, and it was felt that they should all be checked by observation of healthy families belonging to the same social class and living under, as nearly as possible, the same conditions. This has been done in the present investigation, and a comparison has also been made with children belonging to the same class of society, but brought up under more ideal hygienic conditions. The places selected for this comparison were the garden cities of Bournville and Port Sunlight.

As only some of the factors which might tend to the development of rickets had been considered by Findlay, a more comprehensive scheme of investigation was formulated embracing the following additional points:—

1. The parentage of the child.
2. The previous health of the child.
3. (*a*) The diet of the child prior to the onset of rickets, and (*b*) the diet of families with rachitic children compared with that of families with healthy children.
4. The size of the family, and the condition of the other children.
5. The family income.
6. The general character of the housing.

To enable the studies to be systematically carried out the following schedule was drawn up and used in each case by the visitor.

Schedule

A Child Affected with Rickets

Name ..... Address .....
Age ..... Sex .....
Which child in family ?
Number of children in family
Can child sit ?
Can child stand ?
Can child walk with or without support ?
When did child learn to walk ?
Anterior fontanelle.
Teeth.
Condition of ribs
Condition of limbs
Facial phenomenon
Laryngeal spasm
Convulsions ..... if so, when was first convulsion ?
Is child still taking convulsions ?
How long was child at the breast ?
When was extra feeding commenced ?
Nature of extra feeding —
When was the child noticed not to be thriving ?
How often is child taken out daily ?
How long is child kept out daily ?
Condition of bowels.

B Family History

Father Age ..... Nationality .....
Occupation
(*a*) Regular
(*b*) Irregular
Town or country bred.
General condition
Habits—drink &c.
Previous health

Mother Age ..... Nationality .....
Town or country bred
General condition
Habits—alcohol, &c.
Number of pregnancies
Number of still-births
Number of miscarriages
Health before and during pregnancy.
Health during lactation

Other children
Age
Sex
Condition with special reference to rickets and tetany

C. Housing.

Position on map.
Surroundings.
Approaches.
Has the house through ventilation?
Number of stairs up.
Number of rooms.
Size of rooms.
Window space.
Exposure of rooms.
Number of inmates.
Are lodgers kept? Number of lodgers.

General conditions with special reference to—
Cleanliness.
Sanitary arrangements.
Ventilation.
Rent.

D. Financial Condition.

Income.
Expenditure.
Rent.
Food, &c.

Source of Cases.

The names of the families with cases of rickets were obtained from the Dispensary of the Royal Hospital for Sick Children, Glasgow. As a weekly list of the newly-registered cases of rickets was supplied, the children visited were suffering for the most part from the disease in the active stage. They were divided according to the severity of the condition. The children presenting severe bony deformities and unable to walk were grouped under the heading "marked rickets." The less pronounced cases showing slighter osseous changes with backwardness in teething and walking were classified as "mild rickets." Many of those latter, of course, may only have been at the commencement of what would eventually become severe examples of the disease. The cases which at the time of visit appeared to be healed—that is had ceased to sweat at night, had every appearance of normal health, and could walk quite well, although presenting deformities—were classed by themselves as "healed rickets," and in this group an effort was made to discover what differences existed in the home conditions during and subsequent to the active period of the disease.

The names of the non-rachitic children were also collected at the Dispensary of the Royal Hospital for Sick Children by Sister Elmer, who noted the name of every non-rachitic family with children of suitable age who attended the clinic till the necessary number was gathered. In addition to this a few healthy families were suggested by the workers at two centres of social activity in poor districts of the city.

The rachitic and non-rachitic children were from the same social class and living under practically the same general social conditions.

Method of Investigation

In every case the home was visited and the schedule filled during conversation with the mother, who, when the object of the investigation was explained, readily answered all questions and gave every facility for observation. No effort was made to test the statements of the mother by making any enquiries in the neighbourhood.

The statistical value of the following figures lies in its favour:—

1. That the cases practically all came from the same source in the order in which they were presented there for treatment.
2. That one visit at least was paid to each house by the same visitor.

This gives uniformity to the observations on points of detail that could be dealt with only by statistical terms.

Number of Children Investigated

Two hundred families with cases of rickets, one hundred and fifty of mild, and one hundred of apparently healed rickets were studied. Two hundred families of non-rachitic children were also visited.

The information has been tabulated in groups of 100 in the exact order in which the visits were made, the first 100 visits being made between April and October, 1915, the second 100 intermittently between October, 1915, and November, 1916. This method of tabulating was adopted on account of the smallness of the number of families which could be included in such a detailed study. Thus the accuracy of the results obtained could be tested by the degree of correspondence existing between the earlier and the more recently collected statistics. On almost every point there was a very close agreement between the facts collected concerning the first and the second 100 families. Where any difference existed the figures are given for each 100 separately in the tables. The charts which follow combine the results.

Dr. Pearce has in the introduction dealt with the previous work done upon the influence of the different factors studied.

2. Family History

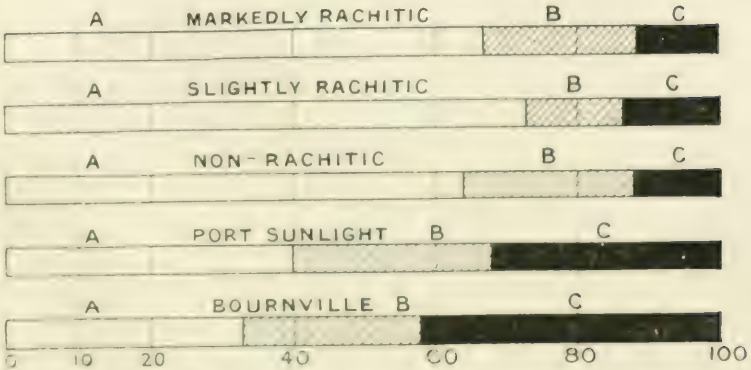
(a) *Parents Town or Country Bred*

The health and habits of the parents may act upon the child either directly or by their effect upon the conditions of the home.

Cheadle[2] held that parentage was of little importance in the production of rickets compared with external conditions, whereas

CHART I.

PERCENTAGE OF FAMILIES IN WHICH PARENTS ARE COUNTRY BRED.



Siegert[3] came to the conclusion that rickets in the parents was a factor of great importance in the production of the disease. MacGregor[4] found that the children of city-bred parents were more liable to the disease than those of country-bred parents. Of 1,277 children between the ages of 6 months and 10 years admitted to the Glasgow Fever Hospital, 44·4 per cent. of those born in Glasgow of Glasgow parentage, 33·8 per cent. of those born in Glasgow but having country-bred parents, and 25·4 per cent. of country-born children of country parentage showed evidence of rickets.

In the present investigation most of the children examined were born and reared in Glasgow, and the greater number of the parents of both the healthy and the rachitic families were also born and brought up in Glasgow. Of those parents who did not belong to Glasgow most were Irish, the others being English, Jewish, Italian, or coming from other parts of Scotland.

Although as Chart 1 brings out the proportion of families in which one or other of the parents was country bred was slightly greater in the non rachitic families than in the rachitic, practically the same proportion—that is, just over 10 per cent. of the rachitic and of the healthy families—came of parents who had both been brought up in the country.

In the first groups of 100, 6 of the non rachitic, 10 of the mildly rachitic, and 12 of the markedly rachitic children were of Irish peasant parentage. While rickets is uncommon in the country districts of Ireland, it appears to be prevalent among the Irish population of Glasgow, who generally come to Scotland poorly equipped for the economic struggle, and consequently are not so well housed or fed as their Scottish neighbours.

The fact that the majority of the parents in each group of markedly, mildly, and non rachitic families were of Glasgow extraction counterbalances any slight difference present, *and is distinctly against the theory that parentage, so far as birth in town or country is concerned, bears any part in the production of the disease*.

(ii) *The Mother.*

(*a*) *Health*

The mothers of all the families were closely questioned concerning (*a*) their general health and condition, (*b*) their health during pregnancy, (*c*) their health during lactation, and (*d*) whether they had had any still-births or miscarriages.

A greater number of the mothers of the non rachitic children were found to be in good health than was the case with the rachitic. Many of the latter looked anæmic and nervous, and seemed to have quite lost heart in their families. Although, owing to the indefinite nature of such information, the point was

...ere studied with care, it was ascertained that some of them had been rachitic as children although only a few were noticeably deformed by the disease. The mothers of the non-rachitic children generally looked fresher, healthier and more intelligent. This, however, was by no means invariable, as often strong country-bred people were found to have rachitic children.

An effort has been made to express the difference by classifying (a) the mother's general health, (b) her health during pregnancy, (c) her health during lactation, under the relative terms good, fair and poor. The results have been tabulated below and (a) has been graphically expressed in Chart II. (a) was drawn up with reference to the appearance of the mother and to her statements with regard to her own health at the time of the visit; (b) refers to the mother's statements concerning her health during the pregnancy prior to the birth of the child studied in the investigation; and (c) to the following period of lactation.

The figures are as follows:—

(a) General Health and Condition.

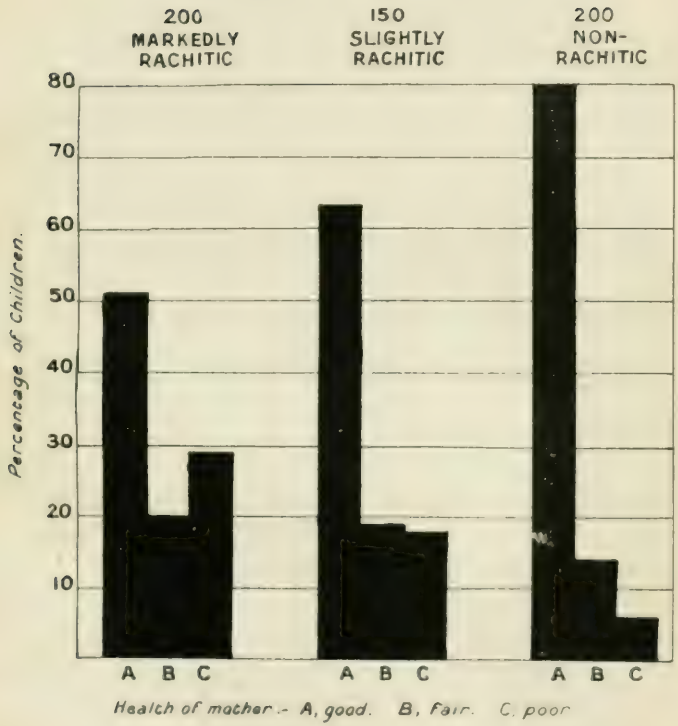
	[illegible] (per cent.)			[illegible] (per cent.)			[illegible] (per cent.)		
	1 to 100	101 to 200	Average	1 to 100	101 to 180	Average	1 to 100	101 to 200	Average
Good	62	40	51	64	62	63	86	81	84
Fair	17	24	20.8	20	18	19	10	13	11
Poor	21	36	28.2	16	20	18	4	6	5

(b) Health During Pregnancy.

	[illegible] (per cent.)			[illegible] (per cent.)			[illegible] (per cent.)		
	1 to 100	101 to 200	Average	1 to 100	101 to 180	Average	1 to 100	100 to 200	Average
Good	68	58	66.8	69	80	72	81	86	82
Fair	8	18	12	16	4	14	8	8	8
Poor	24	42	33.8	18	16	17	10	8	9

CHART II.

HEALTH OF MOTHER.



(c) Health During Lactation.

	Severe rickets (per cent.)			Slight rickets (per cent.)			Non-rachitic (per cent.)		
	1 to 100	101 to 200	Average.	1 to 100	101 to 150.	Average.	1 to 100	101 to 200	Average.
Good	64	54	59	71	81	74	87	81	84
Fair	9	15	12	21	6	16	6	12	9
Poor	27	31	29	8	13	10	7	7	7

From these figures it appears that, although there was a distinct difference in favour of the mothers of the non-rachitic children, even in the rachitic families more than half of the mothers were apparently in normal health. *The state of the health of the mother can at most be regarded as a contributory factor in the development of rickets, and may very possibly be merely an index of the social conditions.*

(d) Still-births and Miscarriages.

	1 to 100		101 to 200	
	No. of mothers who have had still births or mis-carriages.	No. of still births or mis-carriages.	No. of mothers who have had still-births or mis-carriages.	No. of still births or mis-carriages.
Marked rickets	25	32	27	47
Mild rickets	21	34	20*	28
Non-rachitic	22	39	17	30

* The figures in the second group of mild rickets are percentages calculated from only 50 families.

The average number of pregnancies that the mothers of the markedly rachitic families had had was 5·72, of the mildly 4·83 and of the non-rachitic 4·22. That is, the average rachitic family was larger than the non-rachitic. Consequently by deducting the above almost equal number of miscarriages and still births from the rachitic and non-rachitic families the proportionate

difference as the size of the families is increased. This is probably the only manner in which the number of miscarriages influences the question of rickets. *The difference in the figures is too small to support the existence of any causal connection between the tendency to miscarriage and the production of children prone to rickets.*

(b) Habits.

Marked Rickets.

Twenty-seven per cent. of the markedly rachitic families were manifestly neglected. The children in these families were extremely dirty or verminous, the mothers slovenly and untidy, and the house showed evidence of neglect. In many of these cases the mother was known to take drink. Twenty-nine per cent. of the mothers of the markedly rachitic children were careless. They were not wilfully neglectful, but still the children did not receive sufficient attention. Either the children were not kept clean, their feeding appeared to be irregular and unsatisfactory, or they were allowed to sit for hours at a time on a cold floor or chair, and were not taken out till late evening, when perhaps a visit was paid to a picture theatre. The remaining proportion (44 per cent.) of the marked cases of rickets were apparently well cared for, although often undue anxiety about the child, coupled with ignorance led the mother into error: as for instance, when in fear of cold the infant was confined to the house for a protracted period, or was so overladen with clothing as to interfere with respiration and freedom of movement.

Slight Rickets.

The children with slight rickets had in 14 per cent. of the families been neglected, in 30 per cent. had received little care, and in 56 per cent. had apparently been well cared for.

Non-rachitic Cases.

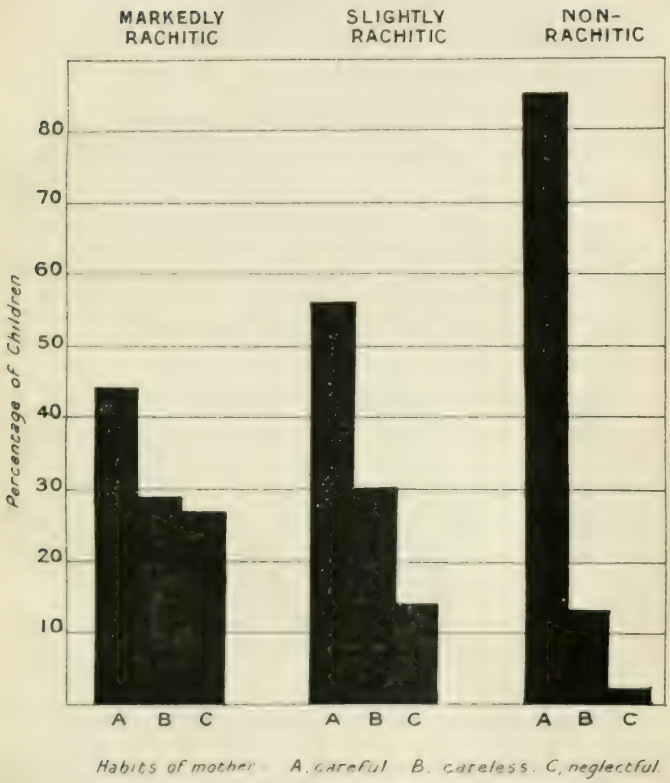
Most of the mothers of the non-rachitic children, on the other hand, were careful and intelligent, only 2 per cent. appearing to be neglectful and 13 per cent. careless. The children appeared to be their first thought, and everything possible was done to render the conditions under which they lived hygienic.

Chart III. depicts the habits of the mothers according as the children appeared to be neglected, carelessly looked after, or well cared for.

The most striking difference between the mothers of the rachitic and of the healthy children was one of personality and expressed itself in the better care bestowed on the non-rachitic families.

CHART III.

HABITS OF MOTHER.



Habits of mother — A. careful B. careless. C, neglectful.

(iii) *The Father.*

(*a.*) *Health.*

In very few instances was the father at home when the visitor called, so that the information on this point was usually supplied by his wife.

Although a slightly greater number of the fathers of the rachitic than of the healthy families appeared to be under the normal in health, the difference was not so marked as in the case of the mothers.

Health of the Father.

	Severe rickets (per cent.)			Slight rickets (per cent.)			Non-rachitic (per cent.)		
	1 to 100	101 to 200.	Average.	1 to 100	101 to 150	Average.	1 to 100	101 to 200	Average
Good ...	83	76	79	79	70	76	97	81	89
Fair	2	11	7	14	10	13	2	9	5
Poor ...	15	13	14	7	20	11	1	10	6

(*b*) *Habits.*

The faults of character which existed in the mothers of the rachitic children were noticeable also in the case of the fathers. From a few leading questions put to the mothers with the object of discovering whether the father took drink, it appeared that a considerable proportion, about 30 per cent., of the fathers of the markedly rachitic children took drink to such an extent that they lost much time from work, or spent in drink so great a proportion of the weekly earnings that the children actually suffered from a shortage of the bare necessities. The families of the excessive drinkers were almost invariably badly housed, clothed and fed, and this although in a number of instances the income was over £3 weekly. About 40 per cent. of the fathers of the markedly rachitic children were very steady, although not necessarily strict abstainers. The remaining 30 per cent. were described by their wives as moderate drinkers, which meant that they were very seldom the worse for drink, did not lose time from work on that account, but were apparently continually spending upon drink money which could not easily be spared from the family needs.

Over 70 per cent. of the fathers of the non-rachitic children were very steady and hard-working.

The figures are —

	Severe rickets (per cent.)			Slight rickets (per cent.)			Non-rachitic (per cent.)		
	1 to 100	101 to 200	Average	1 to 100	101 to 150	Average	1 to 100	101 to 200	Average
Father eating meat	83	24	28·8	18	22	18	11	15	12
Father a non-meat drinker	18	39	28·8	34	66	38	16	36	18
Father a very steady	43	57	40	48	62	44	13	7	7
Neglected mothers	6	9	8	4	6	5	0	0	0

The habits of the father are thus seen to act by modifying the conditions under which the children are reared.

3. The Rachitic Child

(i) *Sex*

Of the children attending the dispensary at Munich from 1876 till 1880 Koenen[2] observed that 4 per cent. of girls and 4·7 per cent. of boys were rachitic. McGregor[3] also found rickets to be slightly more prevalent among boys than among girls, and this was corroborated in the present investigation.

Out of 450 cases of rickets visited, 222 or 49·3 per cent. were females and 228 or 50·7 per cent. males. The corresponding figures for the 200 non-rachitic children were 53 per cent. females and 47 per cent. males.

(ii) *Age*

The children visited were practically all under school age, the great majority being 1 or 2 years old. About 10 per cent. were under 1 year, and 8 per cent. over 3 years. The average age of the children suffering from severe rickets was, at the time of visiting, 2 years and 4 months; of the slight cases 1 year and 8 months; and of the non-rachitic cases almost 3 years. These averages do not give an accurate idea of the age at which the children developed rickets, as in many cases the disease must have been in existence for months before the child was taken to the dispensary and the investigation made.

(iii) *Previous Health and Age of Incidence.*

In the present investigation the development of the child prior to the onset of the disease appeared to have been normal in the majority of cases. Many of the rachitic children were well nourished and healthy in other respects.

The mothers often declared that rickets was the first illness the child had had, and that during infancy the child had given unusually little trouble.

In order to ascertain the most common age of the incidence of the disease an endeavour was made to find out at what age the child ceased to thrive. But it was fully appreciated that such information was rendered less reliable by the possible occurrence of previous illness, malnutrition, &c. The mothers, unfortunately, were too accustomed to seeing children deformed by rickets to think very seriously of it, to note its development, or to feel that there was anything discreditable to themselves in allowing the disease to continue.

The following table shows the information obtained:

Age at which Child Ceased to Thrive.

	Severe rickets				Slight rickets			
	1 to 100.	101 to 200	50 headed cases.	Average per cent.)	1 to 100	101 to 200		Average per cent
[illegible]	23	18	4	18 6	5	3		5 2
[illegible] 3 months	7	6	2	6 0	7	4		5 5
4 to 6 months	1	7	6	5 6	11	3		7
7 to 9 months	7	20	8	12 8	7	11		9 5
10 to 12 months	21	16	7	17 6	19	21		20 0
13 to 15 months	12	8	5	10 6	15	13		14 2
16 to 18 months	5	3	6	5 6	6	11		8 5
[illegible] 2 years	4	3	7	5 6	11	12		11 5
[illegible]	4	1	1	2 4	6	8		7
[illegible]	16	18	7	16 4	10	14		12 6

The table shows that a slightly larger number of the mild than of the severe cases developed the disease late, after having apparently been free from rickets during infancy, and learning to walk at the normal age. This is not because the visits were made while these cases were still at this preliminary stage.

Almost 50 per cent. of the rachitic children were said to have ceased to thrive between 6 and 18 months, at the time when they are usually weaned. Twenty four per cent. of the markedly rachitic and 11 per cent. of the milder cases had ceased to thrive under 3 months, the larger proportion having been weakly from

hours. But what proportion of the non-rachitic children manifested such irritability from birth the present investigation does not show. Sister Schmorl[1] failed to find evidence of rickets in children below 2 months; this probably means that in some cases the disease was preceded by a period of ill-health.

The mothers of course were very ready to ascribe the disease to any illness the child had had. According to the mothers of the markedly rachitic 18 per cent. were delicate from birth, 17 per cent. developed rickets during one of the zymotic diseases, 9 per cent. during other illnesses, excluding diarrhœa. In the remaining 56 per cent. of the cases the mother could put forward no explanation, the child apparently having been in good health till the development of rickets.

(iv) *Seasonal Incidence.*

The seasonal incidence of rickets is well known. Chart IV, which refers to 349 children whose parents were able to say with any certainty when the disease developed, bears out the generally accepted tendency of rickets to make its appearance or worse in spring. 232 children ceased to thrive between December and May, against 117 who developed the disease during the other six months of the year.

(v) *Presence of Tetany.*

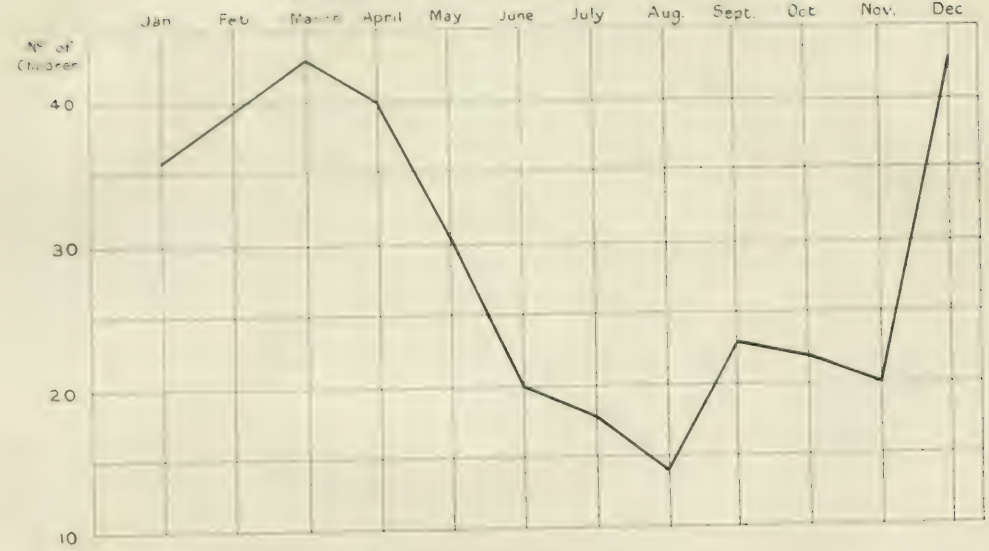
As many writers, most notably Kassowitz[2] and Cheadle[3], have held that tetany is simply one manifestation of rickets, special attention has been paid to its presence or absence in the children investigated. The term "tetany" is used in its broadest sense as signifying the clinical entity characterised in the active stage by infantile eclampsia, laryngismus and carpopedal spasm, and in the latent stage by increased mechanical and electrical excitability of the peripheral nerves. The increased mechanical excitability can be demonstrated by the presence of the facial or Chvostek's phenomenon. Since practically all the information was obtained in the patients' homes, there were no opportunities for testing the degree of electrical excitability. But as shown by Findlay[4] and Harvier[5] the facial phenomenon is probably the most delicate test and this was used by us.

Although tetany has, of course, been known to occur independently of rickets, at least in adults, consequent on gastric dilatation, goitre, and in association with certain occupations, *there was no definite evidence of tetany in any of the non-rachitic children studied.* Occasionally in the case of some of the older members of the non-rachitic families a history of convulsions during childhood was obtained, but these could not unhesitatingly be ascribed to tetany.

On the other hand a considerable proportion of the rachitic children examined showed at the time of visit symptoms of tetany, active or latent, or were reported to have previously suffered from the disease.

CHART IV.

SEASONAL INCIDENCE OF THE DISEASE



The detailed figures are for marked rickets :—

	1 to 100	101 to 200	Average percentages.
(*a*) Tetany present	41	23	32
(*b*) A history of tetany	13	9	11
(*c*) No evidence of tetany	46	68	57

and for the slightly rachitic :—

	1 to 100.	101 to 150.	Average percentages.
(*a*) Tetany present	25	30	27
(*b*) A history of tetany	16	10	14
(*c*) No evidence of tetany	59	60	59

That is, 43 per cent. of the markedly rachitic and 41 per cent. of the slightly rachitic children had suffered from tetany.

The great discrepancy between the presence or absence of tetany in the two groups of 100 cases of marked rickets is probably due to the season of the year at which the cases were investigated. Tetany, like rickets, presents a definite seasonal incidence, being more prevalent in the late winter and spring and least frequent in summer and autumn. Of the first group of severe rickets 84 were visited in spring and the remainder in August, whereas of the second group of 100 cases 60 were visited in autumn and only 40 in spring.

It will be seen from the table of the percentages of tetany in cases of slight and of marked rickets, the presence or absence of tetany did not seem to have any relationship to the severity of the rachitic manifestations.

Very often the children who had severe tetany had very slight rickets, and the children with marked rachitic deformities presented no evidence of tetany. And further, as is seen from the following table, tetany was demonstrable in a fair proportion of cases with rachitic deformities, but in whom the disease had ceased to be active.

[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]

. It will be noticed that of the healed cases of rickets 75 per cent. gave no history of tetany whereas of the active cases in only 58 per cent. could no history of tetany be obtained. For this discrepancy there are several possible explanations. In the first place the children in whom rickets was healed were older and what happened during their infancy—the age of rickets and of tetany was less fresh in the mother's memory. It may, however, be that as tetany is a serious complication of rickets and not infrequently fatal, at least in the eclamptic stage, a smaller proportion of those suffering from tetany live long enough for the rachitic process to become healed.

(vi) *Condition of the Bowels.*

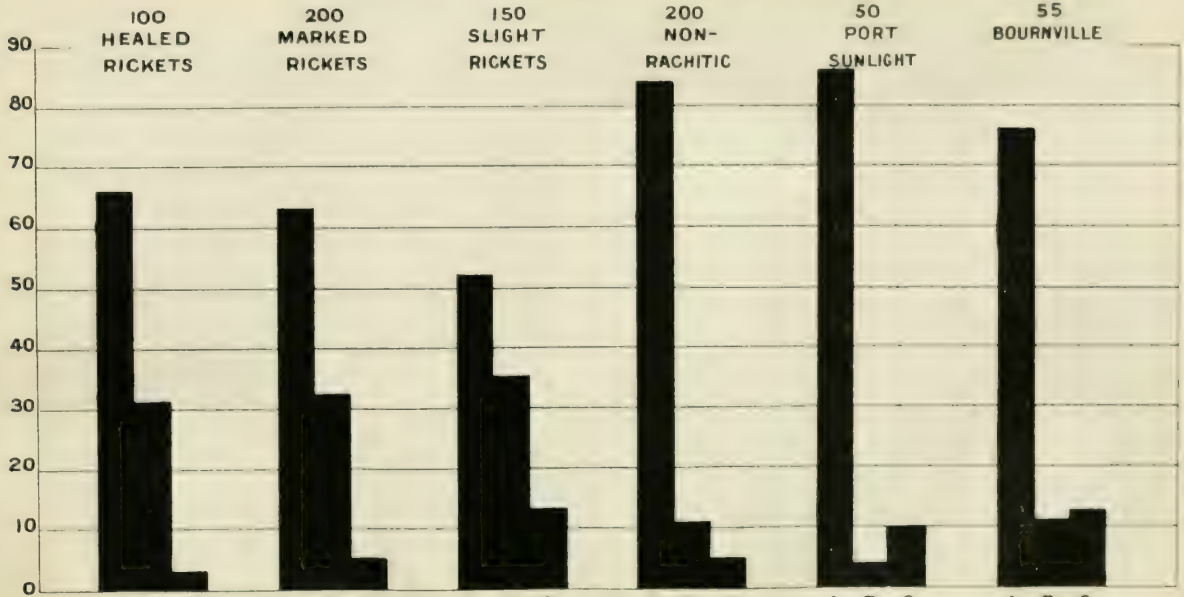
As the theory has been advanced by Marfan[18] and Kassowitz that rickets originates from auto-intoxication from the intestine, the mothers of all the children were closely questioned on the condition of the child's bowels prior to the onset of the disease.

Findlay[1] investigated this point in between 300 and 400 rachitic children. His results did not tend to support this theory since in by far the largest number of cases—nearly 70 per cent.—of those examined, the condition of the bowels was described as regular. The proportion suffering from diarrhœa was about 28 per cent. of the total number. He, however, did not compare these with the corresponding figures for non-rachitic children.

In the present investigation there was a history of diarrhœa in 32·6 per cent. of the cases of rickets while it was present in 14 per cent. of the non-rachitic. The following information has been collected on this point and has been embodied in Chart V.

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

CHART V. CONDITION OF THE BOWELS.



Percentages of children examined whose bowels have been A. Regular. B. Diarrhoea. C. Constipated.

1925

That a slightly greater proportion of the mild than of the marked and of the marked than of the healed cases were said to have had diarrhœa may be due merely to the fact that, as the slight cases were in many instances at the commencement of the disease, the circumstances were fresher in the mind of the mother than was the case with the marked or healed rickets.

Occasionally diarrhœa was found to have set in after rickets, but in the above figures are included only those cases which had suffered from diarrhœa prior to the development of the disease.

In Chart V the figures for Bournville and Port Sunlight have been placed beside those for Glasgow. In both these places, where rickets is very uncommon, intestinal troubles are much less prevalent. This is probably due to the good care which is taken of the infants in these two places.

The difference of at least 20 per cent. in the proportion of rachitic and non rachitic children who had suffered from diarrhœa according to the Glasgow investigation, in spite of the difficulty of getting definite information, suggests that further study should be given to the relationship of intestinal troubles to the onset of the disease. At the same time, as the majority of children in all the groups were free from marked intestinal trouble, this is evidently not an invariable accompaniment of the commencement of rickets.

(vii) *Diet Prior to the Development of Rickets.*

Since rickets has been generally held, in this country at least, to be essentially a diet disease, great care was paid in the present investigation to this question.

Absence of breast feeding, too prolonged breast feeding, deficiency of fat, deficiency of calcium salts in the diet, and overfeeding resulting in the production of gastro-intestinal mischief have all been considered as possible etiological importance (see p. 39).

(a) Length of Time that the Child has been Breast Fed.

The length of time that the child had been breast fed was one of the points studied by Findlay.[1] He found that "the similarity of the rachitic and non rachitic charts is very striking and disposes not only of the idea that want of breast milk, but also as has been assumed, that prolonged suckling is at the root of the mischief."

In the tables dealing with this part of the question the active and healed cases of rickets were grouped according to the bone deformities were marked or slight, giving 250 severe and 200 slight cases.

Length of Time Child has been Breast Fed

Never fed at all	28	27	32	32	15	12·5
1 month	4	4	6	6	7	5·8
2 months	3	3	8	8	5	4·2
3 months	4	4	4	4·8	6	5
4–6 months	17	17	10	12	10	8
7–9 months	17	17	25	29·8	33	16·5
10–12 months	5	5	8	9·5	6	4·8
Over 12 months	30	28	31	37	44	34·5

Never fed at all	15	27	8	16
1 month	3	5·4	3	6
2 months	1	2	2	4
3 months	2	3·6	1	2
4–6 months	4	7	5	10
7–9 months	12	22	5	10
10–12 months	10	18·1	13	26
Over 12 months	8	14·5	13	26

It will be seen from the foregoing tables which are graphically represented in Chart VI., that slightly fewer of the non-rachitic than of the rachitic children were artificially fed from birth, or even from early infancy, and that a correspondingly greater proportion of the non-rachitic than of the rachitic were suckled between 6 months and 1 year.

In Bournville 55 families with young children were visited, and the schedule used in Glasgow was filled in each case with respect to the youngest child of rachitic age. Only 4 rachitic children were observed in all of whom the disease had been very early arrested, and yet 16, that is 27 per cent. of the 55 examined, had been artificially fed from birth. This is more than twice as great as the percentage for the non-rachitic in Glasgow, and is greater than for all the groups of rachitic children. Great care, forgetfulness was taken there with the feeding of the infants, and in most cases gastro-intestinal disorders had been avoided. The percentage of Bournville children who had been breast fed for over a year was 14·5. This is less than the percentage of the Glasgow children who were suckled for that length of time.

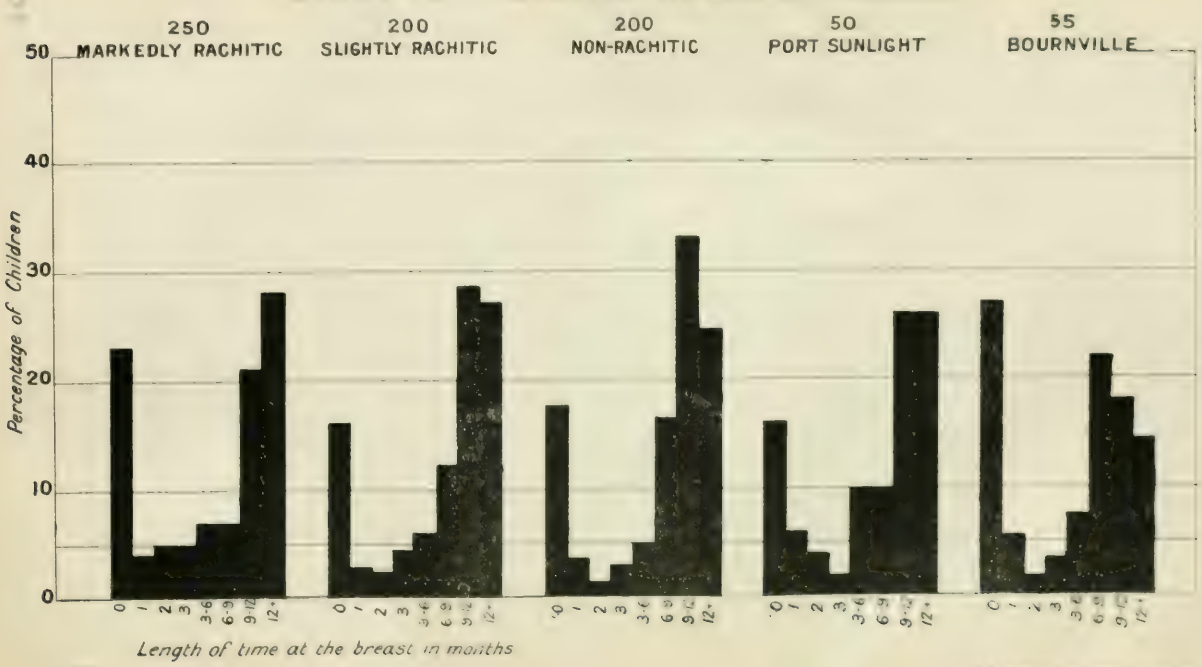


CHART VI. DURATION OF BREAST FEEDING.
250
MARKEDLY RACHITIC
200
SLIGHTLY RACHITIC
200
NON-RACHITIC
50
PORT SUNLIGHT
55
BOURNVILLE
50
40
30
20
10
0
Percentage of Children
0
1
2
3
3-6
6-9
9-12
12+
Length of time at the breast in months
1925

The number of the Bournville children breast fed for six months to one year was 22, or 40 per cent., as against 50 per cent. of the non-rachitic, 41 per cent. of the mildly and 28 per cent. of the markedly rachitic in Glasgow.

Fifty families were visited in Port Sunlight. Of the 50 children studied in detail 6 were rachitic, and of these 6, 5 had been less than two months at the breast. Including these, the Port Sunlight curve for breast feeding is almost identical with that which gives the feeding of the slightly rachitic children in Glasgow.

Moreover, the differences to be observed on this point between the treatment of the rachitic and of the non-rachitic children in Glasgow were slight and were reversed in the case of Bournville, where although the children were healthy, breast feeding in many cases did not seem to be persevered with, probably owing to the fact that the residents belonged to a higher social class.

It would thus appear that lack of breast feeding is not a factor in the causation of rickets, provided that the artificial feeding substituted is abundant, suitable, and carefully given.

(*b*) *Prolonged Suckling.*

Of the 200 non-rachitic children, 24·5 per cent., and of the 450 rachitic children, 27·6 per cent. were breast fed for over one year. This difference appears too small to lend support to the view that prolonged suckling influences the development of rickets.

(*c*) *Sufficiency or Otherwise of Fat in the Diet during Infancy.*

According to Cheadle[2], Bland-Sutton made a number of experiments at the London Zoological Gardens which led him to believe that lack of an adequate proportion of fat in the diet was the cause of rickets. By administering cod liver oil, milk and crushed bone in addition to the ordinary diet of lean meat, he claimed to have reared young animals free from the disease, which had previously been impossible.

These experiments have markedly influenced the opinion, in Britain at least, regarding the cause of the disease.

An attempt was therefore made to determine whether there was an adequate supply of fat in the diet of the rachitic children prior to the development of the disease. In making this estimate regard was paid to whether the child was wholly or only partly at the breast, and if artificially fed to the composition, quantity and frequency of the feeds. Human milk was always taken as of average composition. This was done in view of Schlossmann's[10] analyses which show that up to seven months after delivery the composition of human milk varies little if at all. Findlay in an extensive research on the goat (unpublished) found it almost impossible to vary by diet the composition of the milk, at least so far as the fat, sugar, or protein contents were concerned.

although if little milk were excreted a slightly higher proportion of fat might be present. In the cases entirely breast fed the amount of fat was thus always taken as sufficient. Cows' milk in undiluted state was taken as containing 3 per cent. or a sufficiency of fat, and details regarding the various special foods (Nestlé's, Sister Laura's, &c.) were obtained from the directions on the tins.

In some cases the mother could only give such a vague idea of the child's feeding that it was impossible to form any estimate of the amount of fat received by the child.

From Chart VII, which compares the diets of 231 markedly and 189 mildly rachitic with those of 193 non-rachitic children, regarding whom reliable information was available, it will be seen that 86·5 per cent. of the non-rachitic, 78·3 per cent. of the mild, and 69·7 per cent. of the marked cases had a proportion of fat in the diet, which might be considered sufficient in amount.

Ninety per cent. of the 48 Bournville children whose diet was sufficiently accurately known to allow of an estimation of the proportion of fat, and 87 per cent. of 46 children in Port Sunlight appeared to have had a sufficiency of fat. Three of the 4 rachitic children examined in Bournville had received under the normal supply of fat. In 1 only of the 4, however, was this the only adverse factor in the life of the child. Of the 5 rachitic children in Port Sunlight 2 had received diets which were low in fat.

It is thus seen that in the majority of cases both of rachitic and of non-rachitic children the diet in infancy, whether natural or artificial, contained a sufficiency of fat.

(*d*) *Artificial Feeding*

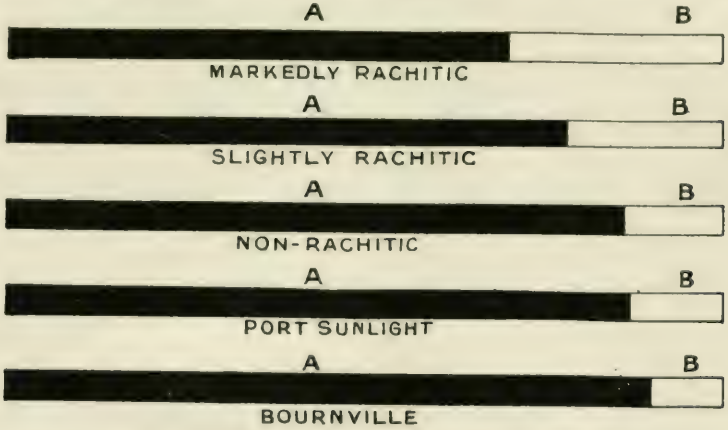
Chart VIII, a curve very similar to Chart VI, illustrates the age of the child in months when artificial feeding was begun, although breast feeding was not necessarily stopped. Fewer of the non-rachitic than of the rachitic were artificially fed under 3 months. The percentages were: Non-rachitic, 22; slightly rachitic, 28; markedly rachitic, 34·4.

Some of the children visited who showed marked evidence of rickets and two of whom were also suffering from tetany, were not yet weaned and had had no artificial feeding whatsoever. Moreover, it did not appear in these cases that the mother was delicate or that the breast feeding was unusually irregularly given, for the great majority of the mothers, both of the rachitic and of the non-rachitic children, gave the breast according to no fixed rule, or at no stated periods, but just when the child seemed to desire it.

Although a slightly larger number of the rachitic children were very ready to get a little of what was going at the family table, the average age at which artificial feeding was commenced varied but slightly in the rachitic and non-rachitic children,

CHART VII.

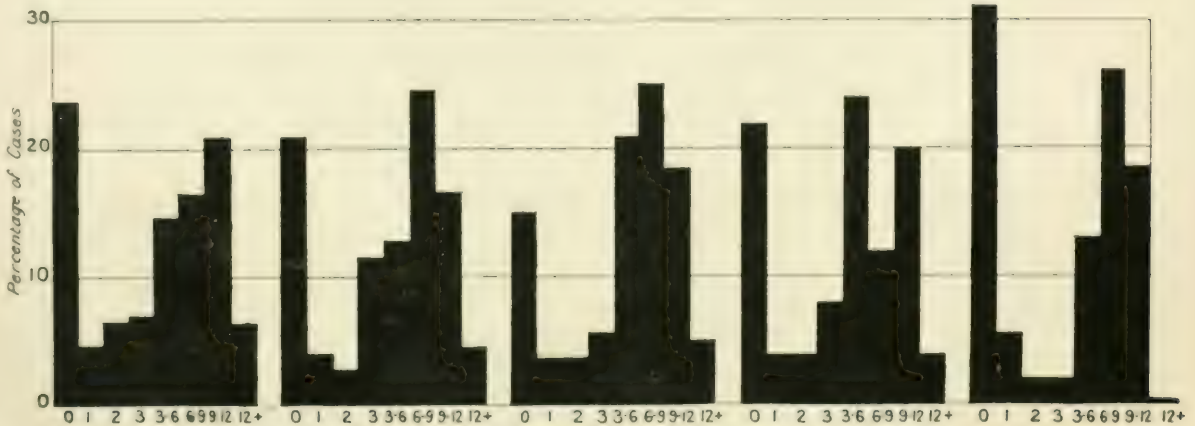
PROPORTION OF CHILDREN WHOSE DIET CONTAINED SUFFICIENT FAT.



Percentage of children whose diets have been A, Sufficient in fat. B, Deficient in fat.

CHART VIII. TIME AT WHICH ARTIFICIAL FEEDING WAS BEGUN.

250	200	200	50	55
MARKEDLY RACHITIC	SLIGHTLY RACHITIC	NON-RACHITIC	PORT SUNLIGHT	BOURNVILLE



1925

This usually occurred between five and six months after birth in the case of the 450 rachitic, and just over six months in the case of the 200 non-rachitic children.

More of the Bournville and Port Sunlight children than of the Glasgow non-rachitic children had received artificial feeding from a very early age, 30 per cent. of the Port Sunlight and 39 per cent. of the Bournville children visited having received artificial feeding under 3 months, and the average age at which extra feeding was commenced being just over 5 months in both these places, just as occurred in the case of the Glasgow rachitic child.

It does not appear that the age at which artificial feeding is commenced is of itself of much importance in the development of rickets.

(c) A Comparison of the Diets of Families with Rachitic and with Non-Rachitic Children.

As shown above, while describing the diet of the rachitic child, it was noted that not infrequently the child began at an early stage in the development of rickets to receive food from the family table. For this reason a comparison was made of the general family diet in healthy and in rachitic families. Twenty-seven rachitic and 20 healthy families were studied. The reasons which decided the choice of the rachitic families were (1) that the children with active rickets were being fed upon "the round of the house," and (2) that more than one child in the family, and in some cases the whole family, had suffered from the disease. In 4 families the disease was apparently healed. All the others had active rickets, although in 4 of the families the rachitic members were only slightly deformed.

The method of study was that adopted by Miss Lindsay[2] in her investigation of the diet of the labouring classes in the city of Glasgow in 1911-12, in the Edinburgh investigations carried out by Professor Noël Paton[13] and others in 1900, and in various other dietary studies in this country and in America. A detailed description of the method is given by Professor Noël Paton, in the introduction to Miss Lindsay's work.

The requirements of each member of the family according to age and sex were set down in terms of the requirements per man per day. The allowances were those used first by Atwater, and adopted by subsequent investigators and were as follows:—

Woman	equivalent to 0·8 of a man at moderate labour		
Boy 14–16	.. 0·8	..	..
Girl 14–16	.. 0·7	..	..
Child 10–13	.. 0·6	..	..
Child 6–9	.. 0·5	..	..
Child 2–5	.. 0·4	..	..
Child under 2	.. 0·3	..	

[illegible] approximating each family to the number of [illegible] men per day to which upon these allowances it was equivalent. The food consumed by the family was readily comparable with that consumed by another and also with the standard set up by the Food Committee of the Royal Society (The Food Supply of the United Kingdom. 1916. cd. 8271. page 3). This body adopted as the minimum requirement for a man at moderate labour the following amounts: 100 g. protein, 100 g. fat and 500 g. carbohydrate, representing 3,000 Cal. daily in the food as purchased.

The Energy Value of the Diet.

There was very little difference in the average energy value of the diets of the rachitic and of the non-rachitic families, and the rachitic families in which the disease was most marked were not always those who had the poorest diet. The diet of two of the families where the disease was marked had an energy value over 3,000 Cal. per man per day, one was between 2,000 Cal. and 3,000 Cal. and one was under 2,000 Cal. per man per day. One of the slightly rachitic families consumed over 3,000 Cal. per man per day, two between 2,000 and 3,000 Cal., and the fourth less than 2,000 Cal. Of the 19 moderately to fully rachitic families 6 had a diet over 3,000 Cal., 8 had a diet between 2,000 Cal. and 3,000 Cal., and 5 had less than 2,000 Cal.

Energy Value of Diet.

	Average.	Lowest.	Highest.
Rachitic	[illegible] Cal.	[illegible] Cal.	[illegible] Cal.
Non-rachitic	[illegible] Cal.	[illegible] Cal.	[illegible] Cal.

Percentage of Rachitic and Non-rachitic Families in relation to the Energy Value of the Diet.

	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

There was no well defined trend in the energy value of rachitic groups. The distribution was regular from 2,500 to 4,000 Cal., with a slightly greater number in each case between 3,000 and 3,500 Cal. Three of the non-rachitic and only one of the rachitic family diets were over 4,000 Cal. These also accounted for the slight

difference between the average energy value of the diets of the rachitic and of the non-rachitic families. Some of the healthy families had a diet low in energy and some of the most markedly rachitic families had a generous diet.

If these diets can be taken as indicating the nutriment secured by the rachitic members of the families, *the disease cannot be said to be caused by the lack of sufficient energy in the food eaten.*

It might be connected, however, as Cheadle[2] and others have suggested, with a deficiency of one or other constituent, and consequently these have been considered in detail.

Protein Content of the Diet.

Fourteen of the 60 families studied by Miss Lindsay were rachitic, and in these the protein intake averaged only 3 grams less per man per day than in the non-rachitic families, while both rachitic and non-rachitic were well above the 100-gram standard.

In the present investigation there was a slightly greater difference in the amount of protein consumed by the rachitic and the non-rachitic families.

	Average	Lower limit	Upper limit
Rachitic .	101·8 g.	70·9 g.	155·8 g.
Non-rachitic .	107·5 g.	61·4 g.	188·4 g.

The distribution was as follows :—

Protein in gms. per man per day	No. of families	
	Rachitic	Non-rachitic
110–100	3	4
120–110	6	3
140–120	3	3
160–140	2	2
	14 = 52%	12 = 60%
90–80	2	4
100–90 g.	3	1
Under 80	8	3
	13 = 48%	8 = 40%

A deficient amount of protein in the diet is not manifestly connected with the development of the disease.

Fat Content of the Diet

In Miss Lindsay's studies the non-rachitic families had on an average 87·3 g. and the rachitic 72·8 g. fat per man per day, a difference of 14·5 gr.

The fat content of the diet of the non-rachitic families in the present investigation averaged 9·4 g. per man per day more than that of the rachitic families.

	Average	Lowest case	Highest case
Rachitic families	87·3 g.	53·0 g.	124·5 g.
Non-rachitic families	96·7 g.	82·4 g.	181·8 g.

Distribution of the Families in relationship to the Fat Content of the Diet

Fat consumed per man per day	Rachitic families 27	Non-rachitic families 29
50–60 g.	2	1
60–70 g.	2	3
70–80 g.	5	—
80–90 g.	5	3
90–100 g.	8	1
	22 = 81·5 %	11 = 38 %
100–110 g.	3	3
110–120 g.	1	5
Over 120 g.	1	4
	5 = 18·5 %	12 = 42 %

While the average fat content of the rachitic diets was lower than that of the non-rachitic, it will be seen that only 4 of the former contained less than 70 g. of fat per man per day. In two of these families the children were markedly rachitic, in another the deformities were only slight. In the fourth the disease, although marked, appeared to be healed. Thus there seems to be no correspondence between the amount of fat consumed and the severity of the disease. For example, in one family (M. 109) each of the 10 children living at home had marked rachitic deformities; none of them had walked before 3 years of age, and at the time of the study the four youngest were still unable to walk; yet the diet had a fat content of 90·9 g., a protein content of 97 g., and an energy value of 3 082 C. per man per day.

Comparison with Healthy Families in Bournville.

Eight dietary studies of healthy families with young children were made in Bournville in May, 1916. In these the weighing was done by the housemothers themselves. The income of these families averaged 48s. weekly, compared with 33s. 11*d.* in the case of the non rachitic and 31s. 9½*d.* in the rachitic families studied in Glasgow.

These eight diets probably on account of the better income, were considerably more generous than the Glasgow diets. The average energy value was 3,698 C., the average protein content 113 grams, and the fat content 122 grams per man per day. None of the families had less than 3,000 C. per man per day, and 4 had over 3,500 C. Three had less than 100 grams of protein, but the lowest had 95 grams.

Two had less than 100 grams of fat, the one having 94 g. and the other 77 grams.

Comparison with Miss Lindsay's Studies in Glasgow.

Mention has already been made of Miss Lindsay's study of the diet of the same social class in 1911-12. She investigated the diets of 60 families of whom 14 had at least 1 rachitic child. In most of these families, as the rachitic member was at school, the disease in all probability was healed. In only 5 of the 14 is it recorded that the children under school age were rachitic. Nevertheless, her results agree with the present in so far as there was practically no difference in the energy value of the diet of the healthy and the rachitic families, a slightly greater intake of protein in the former than in the latter, and a more noticeable difference in the fat content in favour of the non-rachitic.

But although the diets agree in the relative amounts of the various constituents, the families studied in 1915-16 consumed on an average considerably more fat than those studied in 1911-12, and fewer of the diets were low in fat. This is probably accounted for by the increased use of margarine, which was hardly used at all in 1911-12, but which took the place of butter in 60 per cent. of both rachitic and non-rachitic families studied, and provided an adequate supply of fat at a low cost. Since this increase in the consumption of fat is only within the last year or two, less may have been used by the families during the period when the older children developed rickets, but the children with rickets at the active stage were in most cases so young, and the development of the disease so recent, that the conditions were in all probability the same when rickets developed as when the dietary studies were made.

In the present series of dietary studies the rachitic families had as great a fat intake (87·3 g.) as the non-rachitic families had in 1911-12.

There is thus no indication that the absence of the fat soluble growth producing factor in the cheaper margarine[14] played any important part in modifying the onset of the condition.

Comparison with Rural Diets

From figures calculated for Professor Noel Paton from the Board of Trade Returns in 1903 (Cd. 1761) it appears that the fat content of the diets of the rural classes in this country was distinctly below that of the working classes in the cities. The averages were for the English counties 76 g. fat per man per day, for the Scottish counties 81 g., and for Ireland 57 g. Even supposing that an increase in the consumption of fat has taken place in the same proportion as in Glasgow, rural diets will still in all probability be as low in fat as the diets of the rachitic families studied in Glasgow, and it is well known that rickets is very uncommon in rural districts. It is of course possible that deficient absorption of fat rather than defective supply may be the factor of moment in this connection, and further experimental work upon this point is in progress.

Commodities used in the Present Studies.

There was a lack of variety in the food of many of the families. The usual dinner consisted of potatoes and meat—stewed beef, chops or sausages. Occasionally, broth took the place of this. All other meals were composed chiefly of tea, bread and margarine. Owing probably to its price much less meat was consumed by the families studied than is usual in better class families, the average being only slightly over 3 ozs. per man per day. The healthy families had a slightly greater variety of animal food than the rachitic families. In the rachitic families 66·4 per cent. and in the non-rachitic families 59·2 per cent. of the protein consumed came from vegetable sources.

To find whether any difference existed in the suitability of the food for the consumption of young children, the amounts of the chief foodstuffs used have been calculated for both the rachitic and the healthy families.

Average Consumption per "Man" per Day of the Chief Articles of Diet in Grammes.

	Rachitic families	Non-rachitic families
Flour	387·9	376·2
Potatoes	249·6	236·8
Milk	258·0	409·0
Meat	89·1	92·6
Sugar	91·4	84·0
Oatmeal	40·4	36·6
Other cereals	18·6	26·9
Margarine or butter	42·6	38·5
Fish	18·7	35·9
Eggs	18·1	30·4
Cheese	6·7	8·2

Upon the whole the correspondence between the average amounts of the various commodities used is very close.

There is, however, an appreciable difference in the amount of milk consumed by the two groups. While milk was used by all the families the average allowance per "man" per day was 256 c.c. in the rachitic and 309 c.c. in the healthy families. The 27 rachitic families embraced 172, and the 20 healthy families 104 persons. Thus the amount of milk consumed per head by the rachitic families averaged 137 c.c., and by the healthy 189 c.c. per day.

In spite of the difference in the averages, however, it will be seen from the following table that some of the rachitic families were actually having more milk than the non-rachitic.

Distribution of the Families according to the Allowance of Milk per "Man" per Day.

Amount of milk per "man" per day in c.cs.	No. of Families.	
	Rachitic.	Non-rachitic.
Over 700		2
600–700	1	
500–600		1
400–500	2	2
300–400	4	3
200–300	11	5
100–200	6	5
Under 100	3	2

The table shows that no less than 60 per cent. of the non-rachitic families received less than 300 c.cs. of milk per "man" per day, while 74 per cent. of the rachitic families had also less than this amount.

The amount of flour was calculated from all the materials in which it was used. Bread and scones were taken as equivalent to ·75 of their weight of flour. Bread alone supplied over 40 per cent. of the energy in the diets. Oatmeal was eaten by 18 healthy and 21 rachitic families, and, although the amount used was small, it is considerably greater than that consumed by the families which Miss Lindsay studied in 1911-12. The amount used at that time was only 24 g. or less than an ounce per man per day. More use was made of the other cereals by the non-rachitic than by the rachitic families. Thus, along with the greater quantity of milk consumed is accounted for by the fact that more of the mothers of the non rachitic than of the rachitic children took the trouble occasionally to make milk puddings for the children.

Fish was used by 15 or 56 per cent. of the rachitic and 15 or 75 per cent. of the healthy families, eggs by 17 families of each

groups that is by 63 per cent. of the rachitic and 85 per cent. of the healthy families. Although neither of these was much in demand by either group, the rachitic families having only 15 g. of each per man per day, over twice as much was consumed by the non-rachitic as by the rachitic families. Cheese appeared in 15 rachitic and 17 non-rachitic diets, but in small amount. The remainder of the energy in the diets was made up from vegetables, beans and peas, jam and fruit. Carrots, turnips and onions were greatly used, the other commodities but little. Only one diet included fowl or rabbit.

Although a greater regularity in the time of meals was observed in some of the healthy than in the rachitic families, this was by no means an invariable or even a common distinction between the two groups.

Income and Expenditure in Relation to Diet.

The average income of the 27 rachitic families was 31s. 9½*d.* and as the families allowing for differences of age and sex according to the table already given, were equivalent on an average to 3·66 men, this income averaged 8s. 8*d.* per man per week. The non-rachitic families, averaging 3·31 men had an income of 33s., which was equivalent to 9s. 11¾*d.* per man per week.

Amount Spent on Food.

The rachitic families spent 19s. 3*d.* per week or 9¼*d.* per man per day on food. This is equivalent to 60·5 per cent. of the total income. The healthy families spent 64·6 per cent. of their income upon food. This amounted to 21s. 4*d.* per week or 10¼*d.* per man per day on an average.

Arranging the families according as the weekly income per man was above or below 10s., a close relationship appears between the income and the amount spent on food.

Cost of Food per Man per Day.

Income.	Rachitic Families.	Non-rachitic Families.
Above 10s.	10·8*d.*	11s.
Below 10s.	8·1*d.*	10·8*d.*

These figures show that slightly more was spent in proportion to income by the non-rachitic than by the rachitic families.

Comparison of the Energy Value and Protein and Fat Contents of the Diets in Relation to Income.

	Rachitic Families				Non-rachitic families			
Income per man per week.	No. of families.	Average energy value in Calories	Average protein content in gms	Average fat content in gms	No. of families	Average energy value in Calories	Average protein content in gms	Average fat content in gms
Over 10/-	10	3578·3	108·8	95·1	11	3392·7	108·1	101
9/-	4	3296	101·9	94·1	2	4056·4	140·3	87
8/-	2	3306·1	100·6	95·1	4	3286·4	98·1	95·8
7/-	5	3250·5	97·6	79·7	1	2737·5	95·6	84·6
6/-	3	3166	105·4	80·8	1	4174·8	128·8	128·2
Under 6/-	3	2724·1	82·6	66·6	1	2311	61·4	52·4

Excepting the two non rachitic families, who by skill in marketing secured exceptionally generous diets, and thus raised the averages of their respective groups over 4,000 C. per man per day, the amount spent on food and the energy, protein and fat obtained varied directly with income, and it must be remembered that the non-rachitic families are 20 per cent. better off per man per week than the rachitic. Further, the non-rachitic families spent a slightly greater proportion of their income on food, and this enabled them to purchase in greater quantities the expensive protein and fat-containing articles of diet.

The expenditure on rent was 4*s*. 6½*d*. in the non-rachitic and 3*s*. 11½*d*. in the rachitic families. This indicates, as will be shown later, that the healthy children had a considerably greater allowance of air than the rachitic.

Although poorer the rachitic families had a slightly greater remainder of income after allowing for food and rent than the non-rachitic, and as the rachitic children were not so satisfactorily clothed as the others, the probability is that a certain amount of the income was wasted.

(viii) *Air and Exercise.*

In his investigation Findlay[1] found that the majority of the rachitic children had not been regularly taken out at the time when the disease developed, but his study did not give a comparison between rachitic and non-rachitic families, and consequently the results of the present study are of special interest.

Findlay's results agree with the teaching of von Hansemann,[1] who believes that confinement or "domestication" causes the special metabolic error which manifests itself as rickets.

The results of the present investigation fully confirm the conclusions of Findlay on this point. The mothers of the rachitic

children nearly all admitted that they had been unable to take the children out. In some cases they had to go out working themselves; in other cases they had babies who required a great deal of attention, and were in consequence kept indoors; and in not a few instances they had two or more young children and had no facilities for taking them out, being neither able to look after both outside nor to leave one of them at home alone.

The mothers of the non-rachitic children were as a whole very fresh in appearance and fond of going out. Some said that they left the housework to be done in the evening and went out with the children "in the best part of the day." Others declared that their children were just "roughly brought up," outside in all seasons and not unduly muffled up.

In the following tables and in Chart IX an effort has been made to set down the relative amounts of time that the children spent in the open air. Under heading A have been classed all those children who were never taken out or only once or twice a week for a short time. Class B is composed of those who were out for less than an hour daily, probably just for a short time while the mother did shopping, or in the late afternoon when the elder children returned from school. Class C is composed of those who were in the visitor's opinion, taken out sufficiently.

Air and Exercise.

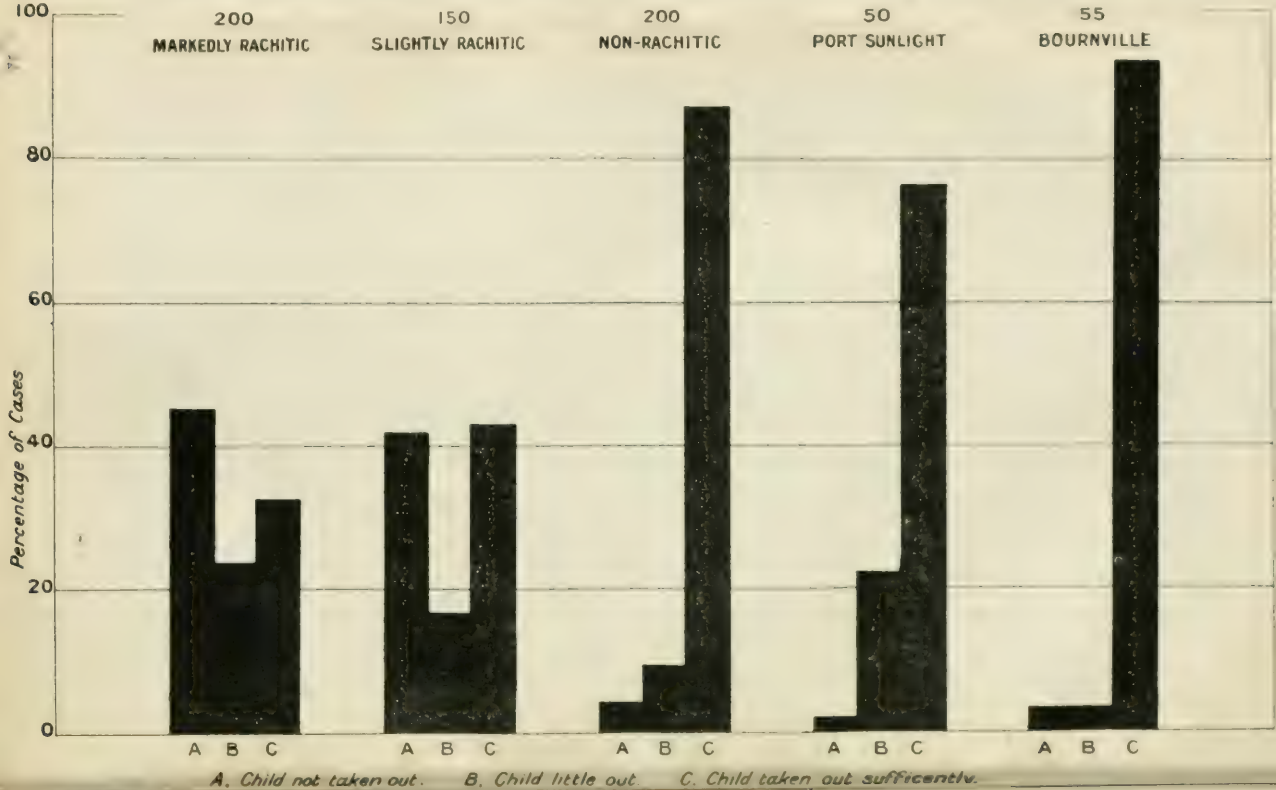
	Percentage of rachitic children marked in Class	Percentage of non-rachitic children marked in Class	Percentage of non-rachitic children marked in Class
(A) Children not taken out	48	31·3	4
(B) Children out rarely	13	18	9·8
(C) Children taken sufficiently	39	50·8	86·3

Over 40 per cent. of the rachitic children had not been taken out, while only 4 per cent. of the non-rachitic had been neglected in this.

The figures perhaps somewhat understate the difference in this respect between the rachitic and non-rachitic, because, while they give the facts as admitted by the mothers, a number of the rachitic children were manifestly neglected and the visitor, while accepting the mother's statements, could not believe that they were taken out as much as was stated. Sometimes for example, when the call was made at mid-day, the rachitic child, still unwashed, and unyet dressed, would be found sitting on the bed having breakfast.

The two groups of 100 gave the same results—that is, that the majority of markedly rachitic children had not been taken out sufficiently. A greater number of those only mildly affected had

CHART IX. RELATIVE AMOUNT OF TIME SPENT IN THE OPEN AIR.



been taken out, but this portion was still less than the half. The great majority of the non-rachitic had been regularly, and for a considerable time, daily in the open air.

The facts concerning the 100 children with healed rickets show most strikingly the influence of this factor upon the development and cure of the disease. As in most of these cases rickets had very recently been active, the general hygienic conditions remained the same, and the housing was generally unaltered. In determining whether the rachitic child had had sufficient air and exercise, the amount of time that the child had spent daily in the open air was ascertained, (*a*) for the period prior to and during the development of the disease, and (*b*) for the period of recovery.

The information collected is as follows:—

(*a*) *Active Stage.*

Child taken out much		27
,, ,, ,, little		15
,, ,, ,, not at all		58

(*b*) *Healed.*

Child taken out much		63
,, ,, ,, little		16
,, ,, ,, not at all		17

Thus the majority of the children were not being taken out when the disease developed, but exactly the reverse was the case when the disease was arrested and healed. It might be suggested that the taking of the children out is merely an index of the care bestowed on the child, but the charts show a much more marked difference in this factor than in general care.

In the garden cities, as would be expected, a much more open air life is led, particularly by the children. The few families where mild rickets was found were noticeably the ones where the least advantage was taken of the facilities for enjoying the fresh air.

The view that lack of fresh air and exercise is an important factor in the development of rickets is further borne out by the differences to be described later in the housing of the rachitic and non-rachitic child of the same social class.

4. The Rachitic Family.

(i) *The Position of the Rachitic Child in the Family.*

One of the points studied by Findlay was the order of the rachitic child in the family. In the chart given by him the number of children with rickets increased from the first to the third place in the family, and then decreased. He surmised that this apparent decrease might be due to the fact that the average family consisted only of four or five children, and the present study proves this to be the case.

The present figures show that the *probability of the onset of rickets increases with the seniority of the child in the family*, the

second being more likely to be affected than the first, the third than the second, and so on. In calculating the relative incidence of rickets, the lesser number of large than of small families has to be allowed for, and hence in determining the relative frequency with which, say, the fourth child is affected, only those families with four or more children must be considered. Chart X is drawn up on those lines. It is not possible owing to the small number of families with more than seven or eight members to draw a reliable curve beyond that point.

The increase was not so great in the case of the slightly rachitic group, in which the disease was more often confined to a single member of the family.

A possible explanation for the increased tendency of rickets to appear in the younger members of the family is that in the labouring man's home the first child has a much greater chance of health than the succeeding children. The mother is fresh and has not become careless. She has nothing to keep her from taking the baby out while her husband is at work. During the infancy of the subsequent children the mother has two or even three young children to look after when she goes out as the ex baby is not usually old enough to go outside by itself to play, when there are the stairs and the dangers of the city streets to be faced. The evil goes on increasing until the oldest child can look after the younger ones. Further the income remains constant as a rule until the older children leave school, so that the food of the younger children is often not so nutritious as that enjoyed by the older ones during the rachitic age. Nor is the air space per person in the home so great, as they do not move to a larger house till the family is large enough to attract the attention of the health authorities. Thus all the evil factors in the life of the child increase with the size of the family.

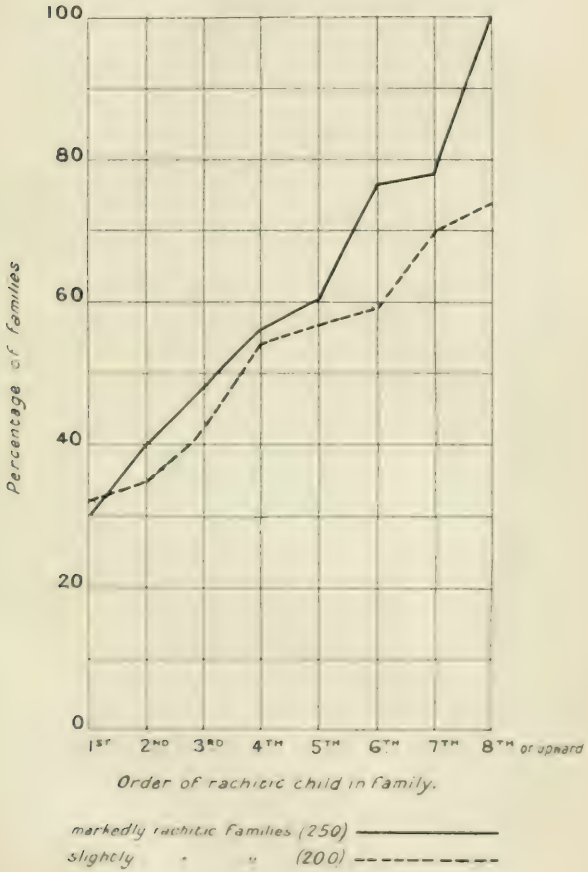
(iii) *Size of the Family*

The rachitic family was larger on the average than the non-rachitic. The following are the figures:—

	Average number of living children born	Average size of the family	Percentage of the children who are dead
1 — 100			
Marked rickets	5·1	4·18	18
Slight rickets	4·25	3·85	16·5
Doubtful rickets	4·89	4·17	14·7
Non-rachitic	3·87	3·33	13·9
100 to 200 —			
Marked rickets	5·31	4·37	17·7
Slight rickets	4·98	4·2	15·7
Non-rachitic	4·53	3·07	13·6

CHART X.

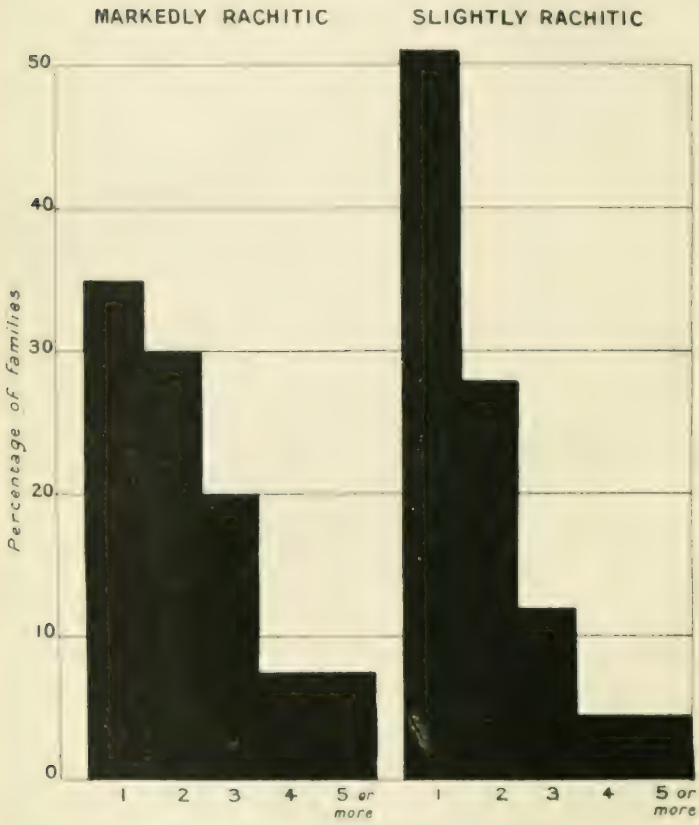
PLACE OF THE RACHITIC CHILD IN THE FAMILY.



H. & C. GRAHAM LTD. LITHO. LONDON S.E.

CHART XI.

NUMBER OF CHILDREN WITH RICKETS IN THE FAMILY.



H. & C. GRANGE LTD LITHO LONDON S.E.

As would be expected from the better conditions under which many of the non-rachitic children lived, and from the possible greater mortality of rachitic children from zymotic disease, fewer deaths had taken place in the non-rachitic than in the rachitic families. Further, the deaths were confined to a smaller number of the non-rachitic families, 55 per cent. of the markedly rachitic, 44 per cent. of the slightly rachitic, but only 35 per cent. of the non-rachitic families having lost one or more children.

(iii) *Condition of Other Children in the Family with Reference to Rickets.*

In the present investigation it was *usually found that several members of the rachitic family were affected by the disease*. The family tendency of rickets is well known and has been taken as supporting the theory that heredity bears a part in its cause. It might also be taken as evidence that rickets is of the nature of an infection, as has been held by Koch[18] and others, but it may simply mean that all the children have been living under identical hygienic conditions.

The extent to which rickets prevailed in the families studied is shown in Chart XI. The second groups of 100 differed slightly from the first, but in each group of "slight rickets" the disease was more often confined to one member than was the case with the markedly rachitic. In the 200 families where the disease was slight 51 per cent. have had only one member, 28 per cent. two and 21 per cent. three or more members rachitic. Of the 250 markedly rachitic families 35 per cent. have had only one child, 30 per cent. two and 35 per cent. three or more rachitic.

In six of the families taken as healthy there was evidence that the disease had existed in one or other of the older members, but this was accounted for by the mother by the fact that some of the home circumstances had been unsatisfactory during the infancy of that particular child. Either the mother had been in poor health and unable to give the child the care it should have had, or she had gone out working while it was a baby, or, while the affected child was at the rachitic age, the family had lived in unhygienic surroundings, *e.g.*, in a damp house in a sunk flat.

5. Social Conditions

(i) *Income.*

Although there was a difference of about 15 per cent. in the average family income between the markedly rachitic and the non-rachitic groups, they belonged to the same social class. The weekly income averaged —

	1–100	101–200	Average of 200
Markedly rachitic	28s. 4½d.	42s. 7½d.	40s. 5½d.
Slightly rachitic	33s. 1d.	43s.	42s. 0½d.
Non-rachitic	31s. 1½d.	38s. 10¼d.	45s.

These studies were made under war conditions when both wages and prices were rising[1] and thus, although the second groups of 100 families each had a slightly higher income, they belonged to the same class as the families visited earlier.

Although the majority approximated to the average, certain of the incomes were very high. Occasionally, when the father was a skilled tradesman, or when the older children were working, the family income was between £4 and £5 per week.

The following table gives the distribution of the families according to income :—

	Rachitic	Slight	Non-rachitic
Under 20/-	[illegible]	[illegible]	[illegible]
20/- to 30/-	[illegible]	[illegible]	[illegible]
30/- to 40/-	[illegible]	[illegible]	[illegible]
over 40/-	[illegible]	[illegible]	[illegible]

It will be seen that 58·4 per cent. of the rachitic and 41·5 per cent. of the non-rachitic families had under 30s. weekly, and that of these the great majority had between 20s. and 30s.

As the non-rachitic family was upon the whole smaller than the rachitic, the difference in the income per person gives a better idea of the relative well-being of the rachitic and the non-rachitic family than a consideration of the total income of the family.

Rachitic	Slight	Non-rachitic
Average income per person per week.	Average income per person per week.	Average income per person per week.
[illegible]	[illegible]	[illegible]

This is a considerably greater difference than appeared in the above tables. In fact the average income per person in the non-rachitic families is greater by 40 per cent. than in families with marked rickets and by 24 per cent. than in families with slight rickets.

(ii) *Expenditure.*

Food.—The only exact figure obtained regarding the amount spent on food are those already given for the families whose diets were studied in detail. From these it appeared that the diet

depended directly on the income. The wealthier families, both rachitic and healthy, spent more on food and had a more generous diet than the poorer.

Housing.—This difference was not apparent to the same extent in the housing. Little improvement was noticed in this respect with an increase of income. In fact, the type of house in which each family resided depended more on the character of the parents than on the income.

The average expenditure on rent was as follows :—

	1–100	101–200	Average of 200
Markedly rachitic ..	3s. 8½d.	5s. 11½d.	3s. 10½d.
Slightly rachitic ...	3s. 11½d.	4s. 1½d.	4s. 0½d.
Non-rachitic	4s. 4½d.	4s. 4½d.	4s. 4½d.

From the results of the dietary studies (see pp. 64 and 71, and also *The Family Budgets and Dietaries of Forty Labouring Class Families in War Time*[17], page 123), it appears that at the prices obtaining in 1915 and the earlier part of 1916 families which had an income of less than 8s. per man per week were unable to purchase a supply of food which reached the standard set up by the Food Committee of the Royal Society[18] as necessary for the proper development and growth of the body, or for the maintenance of a capacity for active work. As the average family may be taken as equivalent to 3·5 men this means a family income of 28s. This figure, of course, fluctuates proportionately with the cost of the commonest foodstuffs. Hence, a great many of the families visited could not have been sufficiently fed, and at the same time properly housed or clothed. This, of course, was what was found, particularly in the case of the rachitic families who were poorer and at the same time did not in many instances utilise in the best possible manner the means at their disposal.

6. Housing.

(i) *The Number of Apartments.*

The housing of the non-rachitic children was markedly better than that of the rachitic, not so much in the situation and locality of the house as in the amount of air space available per person and in the general comfort of the home. All the homes visited consisted of one, two or occasionally three apartments situated for the most part in four storied tenements. A few of the tenements had also a sunk flat or a fifth story. In the better type of houses visited there were usually not more than three dwellings on each flat of the common stair, but in the poorer districts, or where the houses were old and much sub-divided, there were four, five, or

over as many as ten dwellings on each flat. Under these circumstances the passages were long, dark and airless, and the rooms seldom had through ventilation.

MacGregor[1] found that rickets is more prevalent among children living in houses of one apartment than among those living in two apartments, and more common among those from houses of two apartments than of three. Chalmers[2] in an examination of school children found the percentage of rickets among children from three-roomed houses to be slightly higher than the percentages from the smaller houses. This may either indicate, as suggested by Chalmers, that the rachitic children resident in the larger houses have a better chance of survival than those in the smaller, or that the children from homes of three apartments come not from a better social class, but are the younger members of large families who have moved to houses with more accommodation on account of the size of the family and as rickets more frequently attacks the younger children, are therefore more prone to rickets than the older ones were.

The information gathered in the present investigation is —

	No. of families resident in single apartments		No. of families resident in One apartment (each)		No. of families resident in three or more apartments	
		Per cent.		Per cent.		Per cent.
The rachitic families	50	29·8	126	65	15	7·8
The non-rachitic families	37	16	93	62	19	7
The healthy families	21	14	79	70	13	8
The non-rachitic families	49	23·5	120	68	21	9·8

This table does not show any marked difference between the groups.

As, however, the non-rachitic families were smaller as a whole than the rachitic, and many dwelt in larger apartments, there was really a greater disparity in housing than appears here. The difference becomes apparent when the amount of air space per person is considered (p. 82).

(iv) *Districts in which the Children Reside.*

Rickets is essentially a disease of the poorer classes, and is much more common in towns than in the country. Nevertheless, the rachitic and non-rachitic children lived in the same districts of the city, very often in the same streets, in houses on the same story, or even in the same house. Certainly it seems to be more difficult to rear non-rachitic children in districts where the housing is poor than in the more open, better housed neighbourhoods, and that in congested areas it is only with great

care and the exercise of unusual intelligence on the part of the mother that the children can escape the disease. Apart, however, from the fact that throughout the whole city the children are more prone to rickets than country children, the actual conditions of the home, including both defects in construction and in hygiene, are more important than the district in which it is situated. In those areas where the percentage of children suffering from rickets is high, there is the twofold cause—bad housing and bad care—since in these districts homes of the better type are scarce.

The Medical Officer of Health has estimated the population per acre over the whole area of each district, but owing to the large amount of space in some wards absorbed by public works and buildings, his figures do not form a very reliable index of the extent to which overcrowding is present. Even although it were possible to tabulate the overcrowding in the various districts, the number of rachitic children visited in each would only be of restricted assistance in determining the relative prevalence of rickets in the different areas for the following reasons.

1. The children were all attending a free dispensary and consequently all came from the poorer districts.

2. The number of cases which came to the dispensary even from the poorest parts of the city bears no relation to the population of these districts, being influenced by their proximity to the dispensary, the ease with which it can be reached, or whether there is another dispensary near at hand.

The children came from all over the city. In most of the wards there was a very close correspondence between the numbers of rachitic and non-rachitic children visited. A greater number of rachitic than non-rachitic children came from the following districts:—Mile-end, Calton, Dalmarnock, Hutchesontown and Gorbals, while more healthy than rachitic children came from Maryhill, Govanhill, Dennistoun, and Woodside. Anderston and Cowcaddens, although congested and poor, also contributed more healthy than rachitic children to the investigation, owing to the fact that the names of certain non-rachitic families were supplied by the social workers in those districts. The districts where the disease appears to be most prevalent, at least as far as can be judged by the present limited research, are grouped together at the East end of the town on both sides of the river, and the non-rachitic come from the opener and better class neighbourhoods where the housing is more modern. The district from which the greatest number of rachitic children came was Dalmarnock, which is low-lying and smoky, and where there is a great deal of old slum property. Maryhill, which is high lying and openly built and inhabited by tenants of the better working classes supplied by far the largest number of the healthy families. An exception was found in Springburn, where, in spite of its good situation and new well built tenements, rickets appeared to be very prevalent.

(iii) *The Number of Stories up that the House is situated.*

Neither Findlay[1] in his investigation, nor MacGregor[4] in examining children aged from six months to two years presumably with the disease at the active stage discovered any connection between the number of stairs up which the child lived and the prevalence of rickets.

From the present figures also this appears to be a point of little influence, for, although in the first hundred there were more non-rachitic than rachitic families resident on the ground floor at least one story up, there was in the second hundred a slight difference in the other direction, that is, more of the rachitic than of the non-rachitic children lived on the lower stories.

That the number of stairs up the house is situated makes much difference to the amount of time spent by the child in the open air during the rachitic age is doubtful. In a few cases it does undoubtedly, but in the majority of cases the actual home conditions are of much greater influence.

The figures are given in Chart XII.

(iv) *Exposure and Ventilation of the House.*

Regarding the influence of direct sunlight upon rickets it is interesting to note that there was practically no difference in the exposure of the houses of the rachitic and non-rachitic children.

Houses without Through Ventilation.

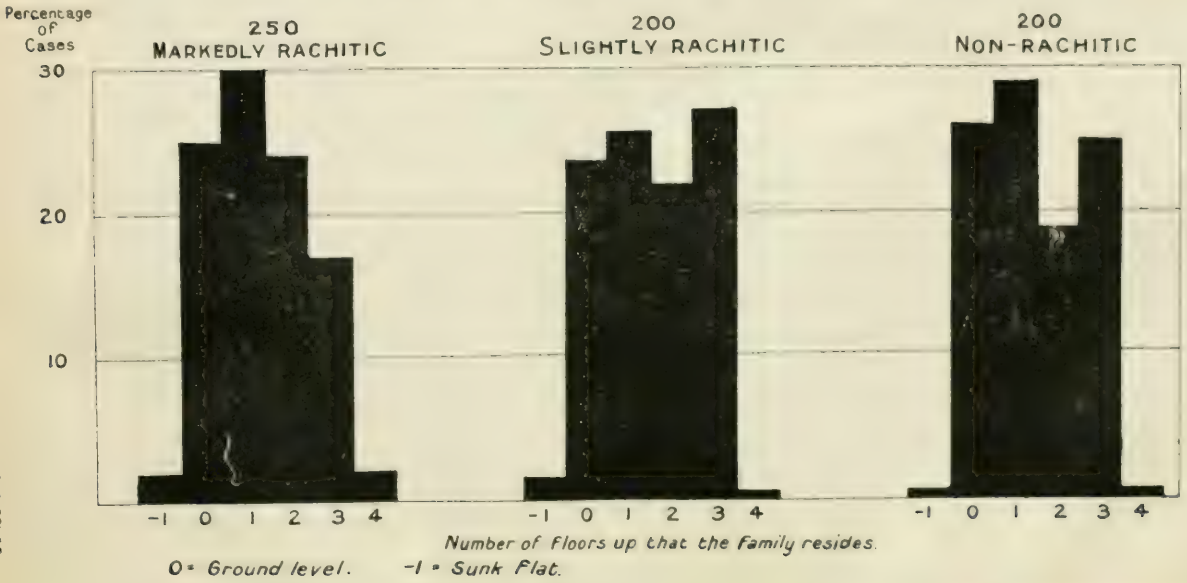
	Rachitic			Non-rachitic					
	1 to 100	101 to 200	Average	1 to 100	101 to 150	Average	1 to 100	101 to 200	Average
Windows facing South	22	16	19	18	8	18	15	10	12·5
Windows facing East	10	19	14·5	15	9	16	18	12	15
Windows facing West	8	12	10	19	10	20	12	10	11
Windows facing North	16	15	15·5	14	10	16	16	13	14·5

Houses with Through Ventilation.

Windows facing South and North	24	19	21·5	20	12	21	24	21	22·5
Windows facing East and West	20	18	19	14	4	17	18	34	24·5

CHART XII.

POSITION OF THE HOUSE IN THE TENEMENT.



Of the houses facing North and South a great many inhabited by both rachitic and non-rachitic families had the kitchen facing north and often so much darkened by surrounding buildings that gas had to be burned during a great part of the day. This arrangement of rooms is to be condemned because of the manner in which the working class family lives in the kitchen and the very restricted use made of the other room. So many of the houses even facing south are so shut in by surrounding buildings that the sun never shines on the windows; and thus the only way in which the sunshine can be enjoyed is by going outside. This, of course, is just what the rachitic children have apparently no opportunity of doing.

Another great defect of the Glasgow housing is seen from the foregoing figures. In every group except one—that being the second hundred non-rachitic children—less than half the houses have a through draught of air. The houses are thus often overheated and airless as well as sunless. Particularly is this the case in the homes of the rachitic families. The child who is never out of the exhausted atmosphere of its home, as would seem to be the rule with the rachitic child (see page 73), appears to suffer more than the child who is out of doors for some hours daily. Also the air in the home is never adequately renewed, if the room is occupied by two or three persons all day.

(v) *Number of Persons to the Apartment.*

Findlay[1] studied the question of overcrowding and deficient air space in the home of the rachitic child by collecting information regarding the number of persons to the apartment in a large number of rachitic families. He found that rickets was increasingly prevalent as the number of persons to the room increased.

The present investigation brings out the difference which exists in this respect between the housing of the rachitic and the non-rachitic children of the same social class. The average number per room was almost one person greater in the markedly rachitic and ·5 of a person greater in the slightly rachitic than was the case in the non-rachitic families. The averages are :—

	Average number of persons to the apartment	
	1 to 100	101 to 200
Markedly rachitic	3·94	3·93
Slightly rachitic	3·5	3·48
Non-rachitic	3·0	2·93

Chart XIII. shows the number of persons to a room in more detail. In this chart the ordinate represents the number of families and the divisions of the abscissa represent the number of persons to a room, the first including all cases where there is an average of less than two persons to a room, the second where there are two or between two and three, and so on. There is a good deal of difference in the curves so obtained. Eighteen or 19 per cent. of the non-rachitic, but only six or 7 per cent. of the markedly rachitic families have an average under two persons to each apartment, while 50 per cent. of the markedly rachitic, 37 per cent. of the slightly rachitic and only 25 per cent. of the non-rachitic families have four or more persons to the apartment. The maximum number inhabiting a single room is six in the case of the non-rachitic and eight in the rachitic families. The mild cases are, upon the whole, better housed than the marked but distinctly more crowded than the non-rachitic.

(vii.) *The Average Air Space per Person.*

The most accurate idea of the extent to which overcrowding prevailed in the families visited has been obtained by calculating the cubic space per person in every family. Where the houses were already "ticketed" the cubic content was noted, and where not it was estimated from measurements taken during the visit.

The average air space per person, adults and children being counted alike, was :—

	1 to 100.	101 to 200.	Average.
	Cubic feet.	Cubic feet.	Cubic feet.
Marked cases	396	447	422
Slight cases	474		474
Non-rachitic	482	514	488
Non-rachitic	868	888	878

The average air space per person is 32 per cent. less in families with cases of marked rickets than in families with non-rachitic children.

The housing of the second groups, particularly of the non-rachitic families, is slightly better than the first, but in each case the non-rachitic children had a much greater allowance of air in their homes than the rachitic, and the families who were markedly deformed by rickets had a much smaller allowance of air than those not so severely affected.

The measurements of the Port Sunlight and Bournville houses visited were supplied by Lever Brothers Ltd. in the former and from the office of the Estate Trust in the latter place, and from

CHART XIII.

NUMBER OF PERSONS PER ROOM.

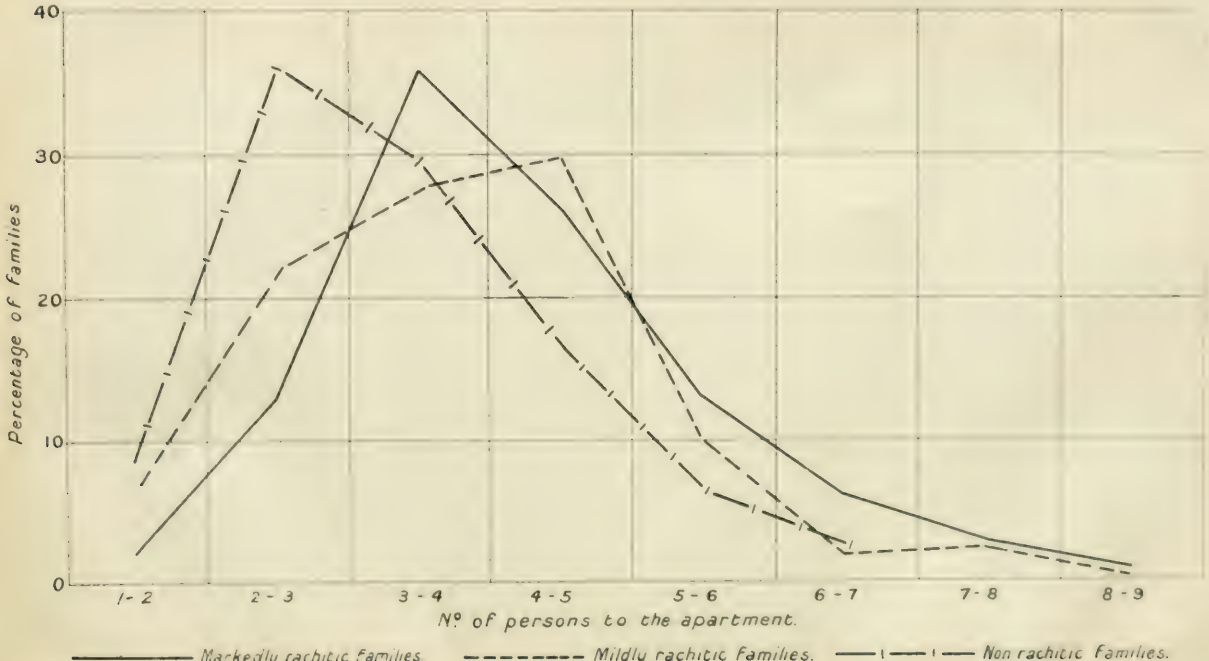
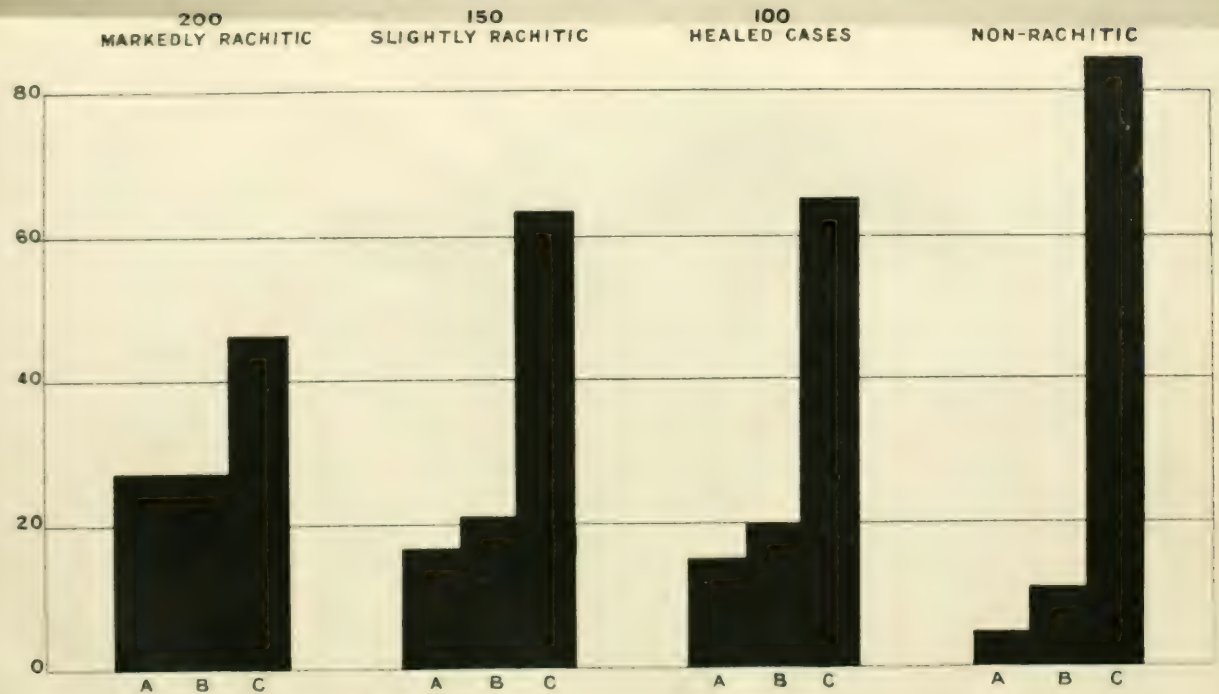


CHART XIV. RELATIVE CARE BESTOWED UPON THE HOME BY THE MOTHERS.



Condition of house – A. Neglected B. Cleanliness fair. C. Very clean.

1928

these the air space has been calculated at 1,568 cubic ft. per person in the Port Sunlight cottages, and 1,196 cubic ft. in Bournville. The actual sleeping accommodation, occupying as it does the upper floor of the houses, may be taken as rather less than half of the above figures. Thus, the cubic space available for each child is much greater in the garden city houses than in the homes of the families visited in Glasgow.

(vii) *Cleanliness of the House.*

A comparison has already been made of the character of the parents of the rachitic and of the healthy families. The healthy children were found to enjoy in the majority of cases much better care than the rachitic, and the same difference was observed in the appearance of the respective homes.

Twenty-seven per cent. of the homes of the markedly rachitic children were neglected. These were dirty and bare, the bed clothes in a very insanitary condition and the atmosphere close and stuffy. Twenty-seven per cent. were untidy and not very well cared for, and 46 per cent. were clean and tidy.

On the other hand, 84·5 per cent. of the homes of the healthy children were clean, well ventilated and well furnished. Of the remainder 4·5 per cent. were bare and insanitary, and 11 per cent. rather untidy and not very clean.

The homes of the less severe cases of rickets occupied an intermediate position, over 60 per cent. being clean and tidy.

Sixty-five per cent. of the homes of the children with healed rickets were found to be clean and comfortable, and from this it would appear, as remarked by Chalmers, that the rachitic children with the better home conditions have a greater chance of survival than those from the neglected homes.

Briefly the differences which were observed between the housing of the rachitic and non-rachitic families were these:

1. *The average number of persons to the room was greater by nearly 25 per cent.*
2. *The average cubic air space available per person was less by 28 per cent.*
3. *Fewer houses as many of the houses were not kept clean.*

7. Bournville and Port Sunlight

A Comparison with Conditions in Glasgow.

If faults in housing and lack of fresh air and exercise are important factors in the cause of rickets, it would be expected that rickets would be of rarer occurrence under better conditions.

To investigate this point, and also to compare the other factors in the child's life, a number of visits were paid in Port Sunlight and in Bournville, and the same information collected as in Glasgow. Port Sunlight constitutes a garden suburb of

Birkenhead, and Bournville though now within the Birmingham municipal area, has all the advantages of rural life along with a carefully planned scheme of housing.

(i) *Vital Statistics*

The health of these villages compared with Glasgow, Birmingham and Liverpool presents a marked contrast.

Death Rate per 1,000 (average for 5 years ending 1913).

Glasgow	17·5
Birmingham ...	14·5
Bournville	5·5
Liverpool ...	21·0
Port Sunlight	8·05

Infant Mortality per 1,000 *Births*

	Glasgow	Birmingham	Birmingham (Garden City)	Liverpool	Port Sunlight	Birkenhead (Garden City)
1911	139	130	46	185	52·6	146
1912	124	111	81	125	81·4	98
1913	128	129	55	132	101·2	139
1914	131	122	83	140	74·2	122
1915	142	118	47	133	101·0	121

(ii) *Health of the Children*

Examination of school children shows that the garden city children are both taller and heavier for their age than the children of Birmingham, Liverpool and Glasgow.

Comparison of Average Heights and Weights

	Age 6 years	Age 8 years	Age 10 years	Age 12 years
Height (Ins.)				
Bournville	45	52·9	61·6	71·8
Birmingham (Essington Street School)	39	47·8	56·1	65·2
Port Sunlight	45·3	54·1	62·6	73·5
Liverpool (E. Council School)	38·7	46·4	54·8	65·7
Glasgow (Rural Schools)	41·4	50·0	59·5	71·9
Weight (Lbs.)				
Bournville	43·5	59·3	82·1	74·7
Birmingham (Essington Street School)	39·4	45·6	53·9	65·7
Port Sunlight	44·7	52·1	62	75
Liverpool (E. Council School)	—	46·7	56·9	67·4
Glasgow (Rural Schools)	40	46·9	57	70·9

Comparison of Average Heights and Weights—contd.

	Age 6 years	Age 8 years	Age 10 years	Age 12 years
Height—Boys.	Ins.	Ins.	Ins.	Ins.
Bournville	44·1	48·3	51·9	54·8
Birmingham (Floodgate Street School)	41·9	46·2	49·6	52·3
Port Sunlight	43·5	48	51·6	54·5
Liverpool (" B " Council Schools)	43	46·7	50·4	54
Glasgow Board Schools ...	42	46	49	53·5
Height—Girls.				
Bournville	44·2	48·6	52·1	56·0
Birmingham (Floodgate Street School)	41·7	44·8	48·1	53·1
Port Sunlight	43·1	46·7	51·3	55·6
Liverpool (" B " Council Schools		46	50·6	54
Glasgow Board Schools ...	41·5	45·7	48·9	53·5

These tables give the comparisons between the garden city children, the children in Liverpool " B " Council Schools, which comprise the same class of the community as the residents in Port Sunlight, the children from Floodgate Street School, one of the poorest districts in Birmingham, and therefore, perhaps, not strictly comparable with the others, and the averages over all the Glasgow Board Schools. It must also be borne in mind that according to the Report of the Anthropometric Committee of the British Association, 1883, the average height in different parts of the United Kingdom shows variations of upwards of 4 inches, and that the Scottish are the tallest of all. Weight in general corresponds with height, the average man in Scotland exceeding the English average by at least 10 lbs.

Rickets.

Of the 50 families visited in Port Sunlight in six families, or 12 per cent. of those visited, the youngest child had had rickets, and in the 55 Bournville families four, or 7·3 per cent., had had very slight rickets, but had recovered. The disease is much more common among the Glasgow working classes. It was only with the greatest difficulty and throughout a period of several months that Sister Elinor could find among the patients at the Dispensary of the Royal Hospital for Sick Children a sufficient number of non-rachitic families for the needs of the present research, whereas any number of rachitic children were available.

No figures with regard to the prevalence of tetany in Glasgow are available, but certainly it would seem to be a common accompaniment of rickets. In the garden cities, however, it, like rickets, is very uncommon, only one child with tetany and one with a history of the disease, both of whom were rachitic, being found in Port Sunlight, and three, two of whom had rickets, in Bournville.

According to the Medical Officers of Health in Liverpool and Birmingham rickets is not nearly so prevalent in those towns as in Glasgow, although more common than in the London cities. Birmingham is reputed to be free from marked cases of rickets. I was informed by Dr Craig, the Assistant Medical Officer of Health to the city, that great difficulty was recently experienced in finding children with sufficiently marked rachitic deformities to photograph for use in an infant health exhibition which was being organised by the medical authorities, but that nevertheless there was a large number of mild cases between the ages of 18 months and two years; and that these were nearly all among housed out children or those living in single apartments situated below the dwellings of 3, 4 and 5 apartments which are general in Birmingham.

School Board records in Glasgow show that the majority of children entering the schools for the physically defective suffer from rickets, the next most common being children with tubercular affections. In Birmingham the greatest number are tuberculous, the second greatest have had infantile paralysis, and the third rickets.

(iii) *Conditions of Living.*

Port Sunlight and Bournville present a marked contrast to any British industrial town, and particularly to the towns of Scotland where the typical workman's dwelling is not a cottage, but consists of one or two apartments in a tenement house of several stories. The Garden City houses also differ widely from the houses of the same class of tenure in Liverpool, Birkenhead and Bournemouth, and in their respective suburban areas. In these suburbs the workmen's dwellings, instead of being tenements as in Glasgow, are nearly all two storied houses of at least four apartments, often possessing a very narrow strip of garden in front and a small yard at the back. The population however, is dense, because of the narrowness of the streets and the habit of subletting parts of the house to other families, and the effect of these long lines of houses, with their drab, soot stained brick walls, is exceedingly monotonous and depressing.

(g) *Port Sunlight.*

Port Sunlight was founded by Lord Leverhulme in 1888 and since then has from time to time been enlarged. His object in building the village was to ensure that the prosperity of the firm should be shared not only by the employees, but also by their wives and children in a more truly beneficial way than would have been possible merely by raising the wages. The houses are

* A description of these gardens (the acquisition of which by tenants [illegible] Cost would not be increased rents, and the tenants pocketed [illegible] [illegible] [illegible]

let at a figure which is just over half their economic rent, the remainder being covered by the firm's "prosperity sharing account." This being so, every householder in the village must, of course, be employed in the Port Sunlight works.

Situation.

Port Sunlight differs little in many points from the adjoining districts of Birkenhead. The ground on which the village has been built is not much above sea level, and before being purchased by Lord Leverhulme was partly occupied by slum property, and partly given over to a swamp through which a tidal river flowed. The old property was cleared away, and the land built up considerably in places. As the ground on which the village now stands is part of the urban district of Lower Bebington, no figures relating to the infant or general death rate prior to the foundation of the village are available for the Port Sunlight area alone. Since the village was founded, the death rates in Lower Bebington have decreased, but not out of proportion to the general decrease all over the country.

General Configuration.

The village occupies about 140 acres of land and has a population of over 4,000. There are at present 800 cottages, and nowhere are there more than ten to an acre. The cottages are built in blocks of from four to seven, in a number of bright and pleasing styles. Instead of being built in rows, the cottages stand in crescents, or squares, with grass parks in front, where the children can play, and looking out in the rear on patches of allotment gardens. Only one-tenth of the ground is covered by houses, the rest being occupied by parks and allotment gardens. All the houses have front lawns 18 to 30 feet wide, which are kept in order by the employers. The works of Lever Brothers are to the south-east, quite out of sight from the greater part of the village. So popular is Port Sunlight that there is always a large number of families waiting for a house. At present the village is being enlarged, 180 houses being in process of construction outside the old boundaries of the village.

The Houses.

The houses are of two types, the kitchen cottage containing a living room, a pantry, and a large scullery with a sink and bath downstairs and three bedrooms upstairs, and the parlour cottage with a parlour downstairs and a bedroom upstairs in addition and about 25 per cent. more in cubic space. All the houses are two storied and the sun can freely enter everywhere. The kitchen cottages are in the majority, and it was entirely among the families resident in these that the visits were paid. There is very little variation in the size of the cottages, although the styles differ. The internal measurements are approximately 22 feet by 18 feet by 18 feet 6 inches. As none of the homes can be

sublet, and as no family, which consists of more than four members may take in lodgers, an adequate supply of fresh air is assured to the children. The average space per person in the 50 houses visited was between 1,500 and 1,600 cubic feet, which is three or four times what the cubic families in Glasgow enjoyed. Most of the cottages have tiled floors downstairs and a tiled yard at the back.

All the houses have baths, although hot water is only given on payment of 9*d.* additional rent weekly. The kitchens are large bright rooms, with big windows, and are never used as sleeping apartments.

Personality of the Tenants.

The families visited practically all belonged to the labouring class, and while originally of rural extraction in the majority of cases, were drawn from a social stratum in Liverpool similar to that studied in Glasgow. Nevertheless, they were very superior. Almost every house was spotlessly clean and well furnished. The women looked neat and healthy in appearance. Most of them not only take very good care of the children, but also bake bread for the family, and make all the children's clothing. The housewives said that there was very little drinking in Port Sunlight, and this was corroborated by the Managing Director of the works. The village social worker only knew of two women whose husbands drank to any extent. The men appeared to be fond of their homes. A great many of them occupied their leisure in gardening or poultry keeping. The work in Port Sunlight is regular, and there is no slackness or unemployment. Families having come to the place stay in it for years, indeed, most of the married women worked there as girls. They are some years later in marrying than is usual in Glasgow. There are only four houses which are larger than the cottages already mentioned, and these are occupied by the clergyman, the social worker, the schoolmaster, and a manager of the works. The residents are absolutely free from undue superintendence, the only restrictions put upon them being with reference to lodgers and the keeping of poultry. Also the married women are not allowed to go out working.

Income and Expenditure.

In pre War times the wages of the unskilled men were 28*s.* weekly, or 7*d.* an hour. In April, 1916, when the visits were made the "lower grade" workmen had a regular wage of 31*s.* and were in addition getting a good deal of payment for overtime work. The average income including this and also anything earned by the eldest children, or any payments made by lodgers, was about 40*s.* weekly. Although complaints were voiced regarding the high cost of living, everyone appeared satisfied with the wages given.

The rent, which with rates varies from 6*s.* to 7*s.* per week for the kitchen cottages, is kept off the wages each week at the works. The average rent of the cottages visited was 6*s.* 8*d.*, or 14·5 per

cent. of the average income, a percentage only slightly higher than that paid in Glasgow for tenement dwellings.

A good deal was spent on food and the diet appeared to be abundant. A great many of the families, for example, had both porridge and bacon and eggs at breakfast. Food prices were practically the same as in Glasgow. The proportion of income remaining for clothing and amusements after providing for rent, heating and food was greater, but before the War it must have been less, as the amount spent on rent was greater and the wages much the same as in Glasgow.

Infant Welfare.

The average number of children in the families was 3·6. The infant mortality has already been stated to be low. The care during infancy appeared to be very good. The children sleep outside in summer and in winter are regularly taken out for walks, not wrapped in shawls as is customary in Scotland, but in perambulators. As soon as they can walk the children play outside a great deal. The following figures kindly supplied by the Editorial and Social Manager of Port Sunlight show how good is the care during the first years of life.

Children entering School

	Port Sunlight and Newferry, 1914–1915	Cheshire County, 1914	Liverpool 1914
Clothing (1) satisfactory	97	93	89·3
(2) unsatisfactory ...	3	7	10·7
Cleanliness (1) clean	98	95	82·2
(2) dirty	1	4	15
(3) pediculi present	1	1	4·4
Nutrition (1) normal	85	87	47·5
(2) below normal	15	12	46·3
(3) bad		1	6·4

These figures would be still further in favour of the Port Sunlight children but for the inclusion with them of the children from Newferry, parts of which are reported to be congested. The fact that Newferry children attend Port Sunlight schools probably also increases the ravages of epidemic diseases in the village, for infection will spread through the schools from the more congested area, and may raise the infantile mortality in Port Sunlight. Bournville has the advantage in this respect, as it has its own schools, and thus the Bournville children are seldom brought into contact with children from outside the village.

Home Conditions of the Six Rachitic Children.

The rachitic children were discovered in the homes where the conditions were the least satisfactory. The main points in the history of these children are as follows :—

P. 2. Eighth child of apparently strong parents; two of the elder children were also rachitic during infancy; mother careless; child never at the breast, but brought up on Nestlé's milk; bowels described as regular; child out each day only for a little while after the other children come from school.

P. 3. Disease very slight; second child of strong parents well reared by; other child had beauty when younger, now apparently healthy; rachitic child 5 weeks at breast, then fed on Savory and Moore's Food; bowels constipated; child out a great deal.

P. 5. Third and fourth members in family of four children show marked rachitic deformities; parents healthy; house untidy; child 2 months at the breast, then fed on Cow and Gate Food; bowels regular; child said to be regularly taken out.

P. 9. Disease marked in the sixth child of a family of eight; fifth and seventh also rachitic; one child dead; family rather neglected; last four children all delicate and wasted during their first year; have all had prolonged diarrhœa and sickness; but have recovered in Port Sunlight hospital; rachitic child 2 months at the breast, then fed on cow's milk and water in equal parts until nearly a year old; irregularly taken out.

P. 12. Health of mother poor; two children dead and three living; all three have been rachitic; are apparently well cared for; child never breast fed; brought up on Nearve; Food and Nestlé's Milk; bowels regular; child very little out owing to the mother's poor health.

P. 30. Third and youngest child, who only came to reside in Port Sunlight at the age of 6 months, is a marked case of rickets; two elder children healthy; mother's health not very good; house untidy; child was premature and always very delicate; was over a year at the breast; bowels constipated. As the child had bronchitis, the mother kept her indoors a great deal; in fact she was seldom out all winter.

(b) *Bournville*

The Bournville Estate lies about four miles south-west from the centre of Birmingham, of which, since the extension of the City Boundaries in 1911, it forms a part. Two villages have already been completed on the estate, and a beginning has been made with a third. The first cottages were built in 1879, but the greater part of the building dates from 1895 and onwards.

The whole property is now in the hands of a body of Trustees by whom it is administered, but the scheme owes its existence to Mr. George Cadbury.

In the deed by which the estate was handed over to the Trustees the founder thus set forth his object:—

"The Founder is desirous of alleviating the evils which arise from the insanitary and insufficient accommodation supplied to

large numbers of the working classes, and of securing to workers in factories some of the advantages of outdoor village life with opportunities for the natural and healthful occupation of cultivating the soil."

The scheme is now, according to the desire of the founder, not only self-supporting, but also contains within itself the principle of continual expansion. As new houses are built, the Trustees are able to fix the rents so as to yield a net 4 per cent. on the cost of construction and site after providing for all outgoings. The income from all sources is now received and administered by the Trustees, and the Trust Deed enacts that, after making full provision for repairs and maintenance it shall be employed in laying out the Estate, in building houses and in purchasing other estates either in the neighbourhood of Birmingham or elsewhere, to be developed in the same way as Bournville.

Situation and General Configuration.

Bournville is well situated. The ground is high-lying and undulating, and the greater part of the village is built on a light sandy soil. The grassy and wooded character of the estate has been skilfully preserved, and adds greatly to the beauty of the village.

The area of the ground to be ultimately laid out for building is over 660 acres, and nowhere are there to be more than seven houses to an acre. There are already over 900 houses and a population which was estimated in 1915 at 4,123. Each house has a long, and almost invariably beautifully kept garden, the average size of which is 500 square yards. In this Bournville differs from Port Sunlight, where the gardens instead of surrounding the houses are grouped together and rented out in allotments, while the grass and shrubs in front of the dwellings are kept in order by the employers. In Bournville great encouragement is given to the tenants in the cultivation of their gardens; gardening classes are held, and there is an Estate nursery, where the necessary plants and seedlings can be procured cheaply. These gardens provide their owners with fruit and vegetables during most of the year, and are estimated to be six times as productive as the ground would be under ordinary agricultural crops, and to add an average of 2s. weekly to the income of each household. The beauty of the gardens and the amount of time which old and young spend out of doors is most impressive to visitors.

The Houses.

The cottages on the estate are in groups of two or four, and in a few instances in E-shaped groups of nine. They are nearly all two storied, and like the Port Sunlight houses, are attractive in appearance and varied in style. The majority of the houses have two sitting rooms, a kitchen or scullery and three bedrooms, and a considerable number are larger than this. The houses

visited, that is, the smaller ones on the Estate, had nearly all a parlour, a kitchen, a scullery and three bedrooms. The smallest houses had two bedrooms, a parlour and a kitchen. All the houses had baths. These were usually constructed to fit into a cabinet in the kitchen or scullery. Many of the cottages were built with a verandah, which almost served as an additional apartment. The measurements of the houses visited were very kindly supplied from the office of the Estate Trust. From these figures the average space per person appeared to be about 1,200 cubic feet.

Personality and Habits of the Tenants.

The majority of the Bournville tenants visited were of rural extraction. Since this was also the case in Port Sunlight it would appear, as might be expected, that the garden cities attract most strongly persons who have had some previous acquaintance with country life. Tenancy is not confined to Bournville workpeople; indeed, less than half the householders are employed by Messrs. Cadbury. The tenants belong mostly to the skilled artisan class and are very intelligent and well educated, and take great care of and pride in their children. A great number are Quakers and have the temperate habits usual in that body. By the command of the Trustees no intoxicating liquor may be sold within the village. The women are very good housewives. A number of them were employed before marriage in Bournville works, where classes are given in housewifery, sewing, cooking, sick nursing and the care of infants. The children are all very well dressed and very healthy in appearance. During the summer many of the families practically live in the open air, taking many of their meals outside. The infants sleep in the garden and, when old enough, play outside all day.

Income and Rent.

The incomes of the families visited varied greatly, but appeared in every case to be sufficient for comfort, and where there was a surplus income it was wisely used, as for example in providing secondary education for the children. In one or two families the father was only a labourer with a small wage, but as the strictest economy was practised these men's homes appeared to be as comfortable and their children as well clothed and fed as the others. The average income of the families visited, including a few cases where the elder children were wage earners, was slightly over £2 15s. weekly.

The rents of the houses not including rates are from 4s. upwards, the greatest number being between 5s. and 6s. per week. Including rates the average rent of the house visited was 7s. 3d. per week.

Infant Welfare.

The health of the children is exceedingly good. The infant mortality, as already shown, is very low. (The average for the 5 years ending 1915 was only 35 per 1,000.) The number of

children to the family averaged 3·36. Altogether only 8 children had died in the 55 families visited; that is, equivalent to only 4·1 per cent. of the infants born. The information collected regarding the various factors bearing on the health of the child is contained in the foregoing tables and charts dealing with the Glasgow children.

Home Conditions of the Four Rachitic Children.

Each of the four cases of rickets had been very slight and was healed, and the other members of the family were apparently free from the disease. The housing and the care bestowed on the children appeared to be as good in these four as in the other Barnville families. Further particulars are:

B. 43. Fifth child in a family of six; parents healthy; rachitic child breast-fed for 12 months, feeding thereafter also good, bowels regular. Until 18 months old the child was only out about thrice a week for an hour or two.

B. 12. Youngest child of a delicate family; mother not at all strong during pregnancy; elder boy tubercular; the girl very ill with kidney trouble. Rachitic child was never at the breast; was fed on milk and barley water until 9 months old, and then on bread and milk and milk puddings; bowels regular. In summer the child slept outside a great deal, but in winter was kept indoors owing to the mother's poor health.

B. 51. Youngest of six children; parents healthy; child delicate from birth, was never at the breast, suffered greatly from sickness, and could only digest cow's milk very much diluted until 10 months old; bowels regular; child out a great deal.

B. 46. The youngest of 3 children; never breast-fed; food from birth until 6 months was milk and water in equal parts, then pure milk and gradually good general feeding. Child throve well till 8 months after birth, when he had severe diarrhœa for a fortnight, after which rickets appeared.

8. Conclusions.

1. Whether the parents are country or town bred has no influence on the incidence of rickets in the children (p. 49).

2. The state of health of the mother is only a contributory factor in the development of rickets in the child in so far as it affects maternal care, or is an index of the conditions under which the child lives (p. 51).

3. The habits of the mother and the care taken of the children have a marked effect (p. 52).

4. The health and habits of the father only act by modifying the social conditions under which the children are reared (p. 54).

5. Rickets affects something like 30 per cent. of the poorer class children in the city of Glasgow. Introduction, p. 18).

6. Rickets is slightly more prevalent among males than among females (p. 34).

7. The most frequent age of occurrence of rickets is between 6 and 18 months (p. 34).

8. Rickets generally develops in late winter and spring (p. 59).

9. Tetany is closely associated with rickets. 42 per cent. of the rachitic children having suffered from tetany. The condition was not observed in any of the non-rachitic children (p. 59).

10. Diarrhœa had been present in 33 per cent. of the rachitic children prior to the commencement of the disease, while only 11 per cent. of the non-rachitic children had suffered from it (p. 58).

11. The duration of breast feeding seems to have no relation to the incidence of the disease (p. 61).

12. The majority of cases of both rachitic and non-rachitic children seem to have had an adequate supply of fat during infancy (p. 62).

13. The age at which artificial feeding is commenced seems to be of little moment (p. 63).

14. The diets of the rachitic and non-rachitic families show no significant difference in energy value or protein content (p. 66).

15. While the amount of fat in the diets of non-rachitic families is, on an average 19·7 per cent. higher than that of the rachitic, the overlap is so great that a defective supply of fat cannot be considered as playing an essential part in the causation of rickets.

16. **The evidence is against a deficiency of milk, of butter, or of the fat soluble A substance being a determining factor** (p. 67).

17. Inadequate air and exercise seem to be potent factors in determining the onset of rickets (p. 72).

18. The probability of rickets increases with the number of children in the family (p. 73).

19. It is usually found that several of a family are affected (p. 76).

20. Although living in the same districts, the social conditions of the non-rachitic family are better than that of the rachitic (p. 77).

21. The district of the city in which the child dwells has not so great an influence on the development of rickets as the actual conditions of the home (p. 78).

22. The average number of persons per room was almost one person greater in the rachitic than in the non-rachitic families (p. 81).

23. The cubic space per person was 32 per cent. less in families with cases of marked rickets than in families who were free from the disease (p. 82).

24. The cleanliness of the house was distinctly better in the non-rachitic than in the rachitic family (p. 83).

25. Rickets is very uncommon in the garden cities of Bournville and Port Sunlight (p. 85).

In conclusion we should like to express our indebtedness to all those who have assisted in any way with the investigation, and, in particular, to mention Sister Elinor (Royal Hospital for Sick Children, Glasgow), Miss Rutherfurd and her assistants (Queen Margaret Settlement), Miss Walker, Miss Lang, Miss Catto and other ladies connected with the Charity Organisation Society, and certain of the women students of the Physiology Class who acted as visitors.

Thanks are also due to the housemothers of the families visited for their co-operation and forbearance.

In connection with the investigations at Port Sunlight we desire to thank Mr. Gray and Mr. Alexander Paul, and with those at Bournville Mr. George Cadbury, Mr. J. H. Barlow, and Mr. Leonard Appleton.

9. References.

1. Findlay: "The Etiology of Rickets," *The Lancet*, 8th May, 1915.

2. Cheadle: *Allbutt's System of Medicine*, 1897, Vol. III, p. 128.

3. Siegert: *Verhand d. Ges. fur Kinderheilkunde*, Kassel, 1903. *Jahrbuch fur Kinderheilkunde*, Bd. 58 and 59.

4. McGregor: *Proceedings of the Glasgow Philosophical Soc.*, Vol. XL, p. 156.

5. Koenen: *Zur geograph. Verbreitung der Rachitis*, Dinert, München, 1886.

6. Schmorl: *Ergebnisse der inneren Medizin und Kinderheilkunde*, Band IV, 1909, p. 403.

7. Kassowitz: *Wiener med. Presse*, 1897, Nos. 4 and 5.

8. Noel Paton, Findlay and Watson: "The Parathyroids," *Journal of Experimental Physiology*, Vol. X, p. 309, 1917.

9. Harvier: *Recherches sur la tetanie et les Glandes Parathyroides*, Paris, 1909, p. 9.

10. Marfan: *Le Rachitisme et sa Pathogenie*, Paris, 1911.

11. Schiemann: "Zur Frage der natürlichen Säuglingsernährung." *Archiv. für Kinderheilkunde*, Band XXX. 1900.

12. Lindsay: *A Study of the Diet of the Labouring Classes in the City of Glasgow*, 1911–1912.

13. Noel Paton, Dunlop, and Inglis: *A Study of the Diet of the Labouring Classes in Edinburgh*. Otto Schulze & Co., Edinburgh. 1900.

14. Halliburton and Drummond: "The Nutritive Value of Margarine and Butter Substitutes with Reference to their Content of the Fat soluble Accessory Growth Substance." *Journal of Physiology*, 1917, Vol. LI. Nos. 4 and 5. p. 235.

15. Von Hansemann: *Berliner Klinische Wochenschrift*. 1906, Nos. 20 and 21.

16. Koch: *Zeitschrift für Hygiene und Infektionskrankheiten*. Bd. LXXII. Heft 2. p. 321.

17. Ferguson: *Proceedings of the Royal Society of Edinburgh*. Vol. XXXVII. pt. II.

18. *The Food Supply of the United Kingdom*. 1916 [cd. 8421], p. 3.

19. Chalmers: *Journal of the Royal San. Inst.*, Vol. XXVI. 1905.

III.—GENERAL CONSIDERATIONS.

By D. Noël Paton and Leonard Findlay.

In the light of the work of previous investigations and of the results of the present study an attempt may be made to formulate the position of our knowledge of the pathology and etiology of rickets, and to indicate on what lines further work is required.

1. Pathology.

In spite of the large amount of work already accomplished many problems in the pathology of rickets are still unsolved. Further research on the chemical and histological changes of the various tissues, *e.g.*, the muscles, and on the metabolism of calcium is required. We do not yet know whether the state of the bones is connected with a decreased transport of calcium to them or to a failure in the developing bone to take up the calcium brought to it. Work upon these subjects is now in progress in this Laboratory.

2. Etiology.

The cause of rickets is still undetermined.

(i) *Inherited Predisposition.*

The present study lends no support to the idea that the disease is inherited or even that there is an inherited predisposition.

In a large proportion of the cases the parents were in all respects strong and healthy, and the tendency of all races of mankind to develop the disease when placed under unfavourable conditions speaks against such an hereditary tendency. But the facts that while rickets is so common in dogs and unknown in cats, and that while it is common in certain breeds of dogs it is comparatively rare in others, seem to indicate that the element of predisposition has to be considered. What the nature of this predisposition may be we do not know. Is it an unusual susceptibility to infection as is the case in tuberculosis, or a family tendency to its development, as is probably the case in cancer?

(ii) *Diet.*

The present results taken in conjunction with experimental investigations in dogs, carried out by Findlay and by Renton and Robertson, give little support to the idea that rickets is due to a dietetic error.

The pups used by Findlay in 1907, and the larger number kept by Renton and Robertson in 1914, all had exactly the same food, yet some became rickety while others did not. It is difficult to come to definite conclusions from experiments upon dogs, since even in the same litter some pups develop the disease sooner and more markedly than others (see figures in Renton and

Robertson's paper), and since even when it develops recovery may take place at any stage without change in their diet. Although the present studies show that the intake of fat and of milk is on the average smaller in rachitic than in non-rachitic families the overlap is so considerable, and the number of non-rachitic children whose diet differs in no respect from those who became rachitic so large, that it does not seem possible to conclude that a deficiency in some constituent of the food is the cause of the disease. It is of course possible that in the urban labouring class families the intake of fat or of some other essential material associated with it is so near the border line that any decrease may be of serious significance, especially if surrounding conditions are exercising an unfavourable influence. Such a possibility is suggested by the results obtained by Hess and Unger on the value of cod liver oil as a prophylactic against the development of rickets in the Negro children in the Negro quarters of New York, where without such treatment a very high proportion of the children develop rickets.

But, on the other hand, the failure to prevent the development of rickets among young carnivores in Zoological Gardens by the addition of fat or cod liver oil to the diet, without due attention to exercise, tells against the theory that deficiency of fat is the determining factor in the onset of the condition.

(iii) *Infection.*

The mode of incidence of the disease is certainly suggestive of an infective nature, but that it is probably not a specific infection would seem to be indicated by its sporadic occurrence in dogs. Nevertheless, our knowledge of the method of the transmission of typhus fever and of trench fever by the body louse and the ease with which the former of these infections can be kept at bay by attention to hygiene indicate at least the possibility of a specific infection in rickets.

The possibility of its being a result of some non-specific infection, similar to the infection of the *Bacillus coli communis*, cannot finally be excluded. The recent work of McCarrison on the production of disturbances in the thyroid and parathyroid glands as a result of infection by contaminated drinking water, and the possibility of cure by removal of the case from the source of the infection suggests that further investigations of the etiology of rickets on these lines is desirable.

(iv) *Social Conditions.*

From the practical point of view, however, these investigations show that certain social conditions which are capable of amelioration exercise a direct effect in favouring the onset of the disease. These are

(*a*) Improper housing,
(*b*) Absence of facilities for open air life,
(*c*) Imperfect parental care.

(α) Insufficient air space in the house, imperfect ventilation, and want of easy access to the outer air are found to be characteristics of those homes of rachitic families (pp. 72 and 81).

(β) Continued confinement in such an atmosphere as shown by the absence of adequate time spent daily out of doors is a factor of even greater importance (p. 71). Whether this acts directly through the continued action of the noxious elements in dirty and badly ventilated rooms, or by depriving the child of desire to exercise its muscular system, it is impossible to state definitely. The fact that animals have been made rachitic apparently simply by depriving them of facilities for exercise seems in favour of the view that the latter factor plays a part (p. 42).

(γ) Want of proper parental care, especially on the part of the mother, is shown to be of no small importance. This is usually not due to indifference or ignorance of her responsibilities, but simply to the fact that as a result of her unfavourable surroundings she has lost the vitality to contend against them. It is, however, possible for even the very poor to rear non-rachitic children, but it requires energy and intelligence on the part of the mother to overcome the adverse influences under which she lives. It is character, intelligence and physical stamina rather than education which is wanted, for without these no instruction is of any use.

The industrial labouring classes form the mass of our population, and it is upon them that we have to depend for its maintenance. The declining birth-rate and the comparatively high infantile death-rate are together tending to check the natural increase. But our investigations show that it is in the larger families that rickets is most frequent, and it would thus seem that an increase in the birth-rate without a concomitant improvement in the surroundings of the children is a measure of doubtful expediency. The first endeavour must be to improve the social conditions in order to conserve and make healthy the life that is already in being rather than to encourage the production of probable weaklings with the necessarily higher wastage.

Unless proper housing and reasonable facilities for outdoor life are provided it is vain to expect that more than a limited number of poor parents in towns will succeed in rearing non-rachitic children, and it is unfortunate for the future of the race that children should be housed under conditions which make their well-being so dependent on the intelligence and energy of their parents.

Whatever be the essential nature of rickets, we feel warranted in drawing the conclusion that by improving these housing conditions the disappearance of the disease would be brought about and mankind relieved of one of the most fertile causes of physical deformity and of the social and economic loss and misery which accompany them.

Printed under the [illegible] of His Majesty's Stationery Office
By [illegible] Limited, [illegible] Street, [illegible] Square, E.C.

NATIONAL HEALTH INSURANCE

MEDICAL RESEARCH COMMITTEE

Reports of the Special Committee upon the Standardization of Pathological Methods

THE DIAGNOSTIC VALUE OF THE WASSERMANN TEST

LONDON
PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE
To be purchased through any Bookseller or directly from
H.M. STATIONERY OFFICE at the following addresses:
Imperial House, Kingsway, London, W.C. 2, and
28 Abingdon Street, London, S.W. 1;
37 Peter Street, Manchester;
1 St. Andrew's Crescent, Cardiff;
23 Forth Street, Edinburgh;
or from E. Ponsonby, Ltd., 116 Grafton Street, Dublin.

1918

Price 1s. *net*

MEDICAL RESEARCH COMMITTEE

The following publications relating to the work of the Medical Research Committee can be purchased through any bookseller, or directly from H.M. Stationery Office at the following addresses: Imperial House, Kingsway, London, W.C. 2, and 28 Abingdon Street, London, S.W. 1; 37 Peter Street, Manchester; 1 St. Andrew's Crescent, Cardiff; 23 Forth Street, Edinburgh; or from E. Ponsonby, Ltd., 116 Grafton Street, Dublin.

First Annual Report of the Medical Research Committee, 1914–1915. [Cd. 8101.] Price 3*d*., post free 4*d*.

Second Annual Report of the Medical Research Committee, 1915–1916. [Cd. 8399.] Price 3½*d*., post free 5*d*.

Third Annual Report of the Medical Research Committee, 1916–1917. [Cd. 8825.] Price 6*d*., post free 7*d*.

Fourth Annual Report of the Medical Research Committee, 1917–1918. [Cd. 8981.] Price 4*d*., post free 6*d*.

Special Report Series

No. 1. First Report of the Special Investigation Committee upon the Incidence of Phthisis in relation to Occupations. The Boot and Shoe Trade. Price 3*d*., post free 4*d*.

No. 2. Report of the Special Advisory Committee upon Bacteriological Studies of Cerebro-spinal Fever during the Epidemic of 1915. Price 6*d*., post free 7½*d*.

No. 3. Bacteriological Studies in the Pathology and Preventive Control of Cerebro-spinal Fever among the Forces during 1915 and 1916. Price 1*s*. 6*d*., post free 1*s*. 8½*d*.

No. 4. Reports upon Investigations in the United Kingdom of Dysentery Cases received from the Eastern Mediterranean.

I. Amœbic Dysentery and the Protozoological Investigation of Cases and Carriers. Price 1*s*., post free 1*s*. 2*d*.

No. 5. II. Report upon 878 Cases of Bacillary Enteritis. Price 1*s*. 6*d*., post free 1*s*. 8*d*.

No. 6. III. Report upon recovered Cases of Intestinal Disease in the Royal Naval Hospital, Haslar, 1915–16.

IV. Report upon combined Clinical and Bacteriological Studies of Dysentery Cases from the Mediterranean. Price 1*s*. 6*d*., post free 1*s*. 8*d*.

No. 7. V. Report upon 2,360 Enteritis 'Convalescents' received at Liverpool from various Expeditionary Forces. Price 2*s*., post free 2*s*. 2½*d*.

MEDICAL RESEARCH COMMITTEE

REPORTS

OF THE

SPECIAL COMMITTEE UPON THE STANDARDIZATION OF PATHOLOGICAL METHODS

No. 4.—THE DIAGNOSTIC VALUE OF THE COMPLEMENT FIXATION TEST IN SYPHILIS, COMMONLY KNOWN AS THE WASSERMANN TEST

Approved for publication by the Medical Research Committee, 7th June, 1918.

Medical Research Committee.

(*National Health Insurance.*)

The Hon. Waldorf Astor, M.P. (*Chairman.*).
The Right Hon. Christopher Addison, M.D., M.P.
The Viscount Goschen, C.B.E. (*Treasurer.*).
C. J. Bond, C.M.G., F.R.C.S. (Hon. Colonel).
Professor William Bulloch, M.D., F.R.S.
Henry Head, M.D., F.R.S., F.R.C.P.
Professor F. G. Hopkins, D.Sc., F.R.S.
Colonel Sir William Leishman, K.C.M.G., C.B., F.R.S.
Professor Noel Paton, M.D., F.R.S.
Sir Walter M. Fletcher, K.B.E., M.D., F.R.S. (*Secretary.*)

In April, 1917, the Medical Research Committee invited the following special Committee to consider how far it may be practicable and desirable to obtain the standardisation of routine pathological methods, and to report to them. The special Committee were empowered to co-opt additional members for particular divisions of their subject.

Colonel J. G. Adami, M.D., F.R.S., C.A.M.C. (*Chairman.*).
Major F. W. Andrewes, M.D., F.R.S., R.A.M.C., T.
Professor William Bulloch, M.D., F.R.S.
Captain S. R. Douglas, I.M.S. (*Secretary.*)

For the consideration of the subjects dealt with in the Report now presented the Special Committee invited the co-operation of Colonel L. W. Harrison, D.S.O., R.H.F., who by permission joined the Committee for this purpose.

FOR INSERTION IN SPECIAL REPORT SERIES, No. 21.

THE DIAGNOSTIC VALUE OF THE WASSERMANN TEST

ERRATA.

Page 11 *Heading. For* 25 *read* 30.

Page 14 *Last two lines of* § 1 *For* McIntosh— Suspicious, Browning— *read* McIntosh—, Browning— (Suspicious).

Page 18. *Line 7. For* "positive incomplete" *read* "Negative."

REPORTS

OF THE

SPECIAL COMMITTEE UPON THE STANDARDIZATION OF PATHOLOGICAL METHODS

No. 4. - THE DIAGNOSTIC VALUE OF THE COMPLEMENT FIXATION TEST IN SYPHILIS, COMMONLY KNOWN AS THE WASSERMANN TEST

CONTENTS

		PAGE
I.	Historical Survey	5
II.	A Report upon the Wassermann Reactions obtained in 191 Cases by Three Independent Observers	30
III.	Tabular Summary of Results	49
IV.	Conclusions	54

In their previous interim Report upon the Wassermann Test (No. I in the present Series) the Committee expressed the opinion that 'there is no process of biochemical diagnosis that gives more trustworthy information or is liable to a smaller margin of error than the Wassermann test when it is performed with completeness and with proper skill and care'.

From time to time instances have been brought to the notice of the Committee in which serious discrepancies have been observed in the results of Wassermann tests made successively upon sera from the same case or simultaneously upon two or more portions of the same serum by different observers. Reported discrepancies are familiar of course to many. Where discrepancy is found the Committee believe that it may almost always be traced to want of experience or skill in the observer or to some failure to perform the test with full completeness. In some instances within their recent knowledge, however discrepancies have been reported which could not be easily assigned, or so it was alleged to any of these possible causes of error. It appeared desirable accordingly to the Committee to arrange a definite trial in which a series of specimens

from patients whose clinical history was known, should be examined by skilled observers of recognized experience, using similar fractions of serum in each case and employing the original Wassermann test with its full controls.

Dr J. H. Sequeira of the London Hospital was good enough to offer his co-operation, and undertook to select from among his patients a series of about 100 to include not only treated or untreated cases in which in his opinion syphilitic infection was or had been undoubtedly present, but also those in which his clinical diagnosis was dubious. He was also requested to bring within the series some cases of non-syphilitic disease for additional purposes of control. While Dr. Sequeira retained his own full clinical notes of all the patients in the series, he arranged to divide the serum, drawn from each into three parts, and to send these three similar fractions, labelled only with appropriate numbers, to three observers invited by the Committee to perform the tests, Colonel L. W. Harrison, Dr. Carl Browning, and Dr. James McIntosh kindly undertook to determine the Wassermann reaction in the specimens provided under these conditions, each worker employing the full method previously described in association with his name in the interim report of the Committee already published: Medical Research Committee, The Wassermann Test, 1918. Special Report Series, No. 14.

In addition the series of sera was tested by Dr. Robert Donald (London Hospital) by means of his drop-technique,[1] which in this instance was a careful copy on a $\frac{1}{5}$ scale of the method of Fildes and McIntosh. Dr. Donald's results appear in the column under his name in Table XIV.

In due course reports upon the tests performed by these pathologists, indexed under the reference numbers attached to the sera, were sent to the Secretary of the Medical Research Committee who had received from Dr. Sequeira the clinical details and his diagnosis of every case given under the corresponding numbers. The results were then collated and are set out below in this report. Dr. Sequeira has also given his own analysis of the results as communicated to him.

The Committee would desire to express their grateful acknowledgements to Dr. Sequeira for the time and labour he has been willing to give to the inquiry, and to the four pathologists who have so generously submitted their work to this open test. The Committee are confident that many others will share with them the sense of obligation under which they have been placed.

By way of introduction to the report now submitted upon the outcome of this trial the Committee have given a historical survey of the Wassermann reaction and of the chief publications which have already been made with reference to its diagnostic value.

[1] Donald, 1915, I, *Brit. Med. Jour.*, 1915, **76** I, 201; Donald, 1915, II, 1045 and Donald, 1916, II, 13.

I. HISTORICAL SURVEY

The history of the so-called Wassermann reaction can be traced back to the discovery of the Bordet-Gengou phenomenon in 1901. These investigators found that when certain antibodies were mixed *in vitro* with their antigens and with complement a reaction of some kind took place whereby the complement disappeared from the mixture. This was shown by the fact that when another antigen, composed of red blood corpuscles, and its homologous amboceptor, were added to the mixture no haemolysis ensued. The complement was described as being 'fixed'. If the first serum did not contain the necessary antibody the complement remained in the mixture, so that the subsequent addition of suitably sensitised red blood corpuscles led to haemolysis. In this way Bordet and Gengou showed that the reaction was specific, and that the method could be utilized for determining whether an antibody was present in a given serum or not. In 1906 Wassermann, in conjunction with Neisser and Bruck, showed that the principle of Bordet and Gengou was applicable to the diagnosis of syphilis, and from this time onward the phenomenon appears in the literature as 'Wassermann's reaction'. Wassermann and his collaborators used as an antigen the extract of the liver from cases of congenital syphilis. Improvements and modifications, however, rapidly took place as the result of researches by Marie and Levaditi, Landsteiner, Müller and Pötzl, Porges and Meier, Levaditi and Yamanouchi, Sachs, Browning, Cruickshank and Mackenzie, Thomsen and Boas, Noguchi, Fibbes and McIntosh, and others. The admirable book of Boas also had a great influence in raising the whole standard of the technique. The Wassermann test began to be practised on a truly gigantic scale all over the world, and rapidly took its place as an important adjunct in the diagnosis of syphilis.

It was very early recognized that in cases of undoubted syphilis the reaction is positive in a large percentage of cases. Already in 1910 Wassermann (5) asserted that with his co-workers he had carried out more than 10,000 examinations and 'we have never yet made a false diagnosis'. Without at present accepting this statement at its face value, and assuming that all serologists are alike competent and trustworthy, it may be pointed out that the diagnostic value of a test like the Wassermann reaction depends largely on the frequency with which a positive reaction is found to occur in undoubted examples of the disease. If the incidence of positive results in these circumstances is an exceedingly high percentage a negative result may possess undoubted significance. It is now a universal experience that positive results occur so frequently in the acute stages of syphilis that a clinical diagnosis which does not coincide requires reconsideration and, if necessary, revision. It is likewise certain that even in the hands of the most skilled serologists a negative result may be met with even in secondary syphilis, and still more is this the case in the tertiary and latent forms of the disease. A negative

reaction, especially if obtained on one occasion, cannot therefore exclude syphilis.

The reputation of the Wassermann test depends on three factors, the serological technique, the serologist himself, and the accuracy of the clinician on whose diagnosis the results of the serologist are judged. But we know that all of these factors are fallible, and thus it is useless to attempt to gauge the value of the test merely by taking all the published series of figures and calculating what appears to be the percentage of correct diagnoses. It is often assumed that a test like the Wassermann reaction can be judged by the frequency with which it satisfies clinical diagnosis; but, in general, clinical diagnosis is a comparative estimate of probabilities, and its nature is such, that the ripe experience of years may be reversed by an accurate scientific method. This is clearly manifest when an analysis of Wassermann tests is made. The agreement with clinical demands is best when sera are sent by a number of clinicians of varied knowledge and experience to be tested, and when the accuracy of the diagnosis cannot be called in question. When, on the other hand, the diagnoses are made after careful consideration and on the basis of a wide and special experience, and when the diagnoses if necessary are reconsidered after further investigation of the case along lines suggested by the serological result, it is found that the test possesses an unusually high degree of specificity.

It is hardly necessary to point out that the ultimate value of the Wassermann test can only be determined by submitting a series of cases to complete examination and this would include not only the clinical opinion, however accurate this may be, but also the demonstration of Spirochæta pallidum where possible, and the pathological anatomical study of material obtained either during life or after death. In spite of the immense number of Wassermann tests which have been performed, the neglect of such precautions has deprived many of them of much of their value. Thus equally positive assertions are made both for and against the test and as the matter is one of paramount practical importance, it is essential that some definite opinion should be arrived at if possible. As far as we have been able to ascertain, the literature contains no case series of any magnitude in which every precaution, clinical, serological and anatomical, has been taken to establish the diagnosis with certainty. In the majority, the value of the Wassermann test has been judged by the exactitude with which clinical demands are satisfied. On account of the modifications and improvements in technique it is justifiable to make some selection of the published results, and it seems fair to separate these results into two great series, those published before and those after the appearance of Bruck's work in 1911.

Bruck (12) has collected the data from the older literature, and has summarized them as follows:

	Total no. of cases	Positive reactions	% of positive reactions
Primary syphilis	1060	629	59 %
Secondary syphilis	3526	3181	90
Tertiary syphilis	1212	1020	84·1
Latent syphilis, early	983	504	51
,, ,, late	1520	605	39
Tabes dorsalis	159	115	72
General paralysis of insane	105	402	99·2

It is thus apparent that in a high percentage of cases of active syphilis the Wassermann reaction is positive. It is equally a fact that in the great majority of diseases which are non-syphilitic the reaction is negative. With improvements in technique the idea has gained ground more and more that with exceedingly few exceptions the reaction is specific for syphilis. While the early publications showed a high percentage of positive reactions in syphilis, the later researches have shown this to be more than could have been suspected. Thus Boas himself has published a careful series of 6043 sera which he tested, with the following results:

Nature of condition	Total no. of cases	Positive reactions	Negative reactions
Primary syphilis	137	99	38
Secondary syphilis: total cases	747	729	18
Secondary syphilis: untreated	437	437	0
Secondary syphilis: recurrences after treatment	310	292	18
Tertiary syphilis: total cases	167	155	12
Tertiary syphilis: not previously treated	132	129	3
Tertiary syphilis: previously treated	35	26	9
Latent syphilis: less than three years after infection	363	143	220
Latent syphilis: more ,, ,, ,,	185	87	98
Tabes dorsalis: total cases	58	40	18
Tabes dorsalis: untreated cases	25	25	0
Tabes dorsalis: treated cases	33	15	18
Dementia paralytica: blood serum	243	243	0
Dementia paralytica: cerebro-spinal fluid	201	189	12
Congenital syphilis: manifest	121	121	0
Congenital syphilis: latent	34	28	6
Congenital weakmindedness	2061	31	2030
Control cases	1927	5	1922
	6043		

Boas's series of 1927 control sera was obtained from individuals either normal or suffering from one or other of nearly 100 different affections regarded as non-syphilitic. In this large series he encountered a positive Wassermann reaction only 5 times. Of these 5 positive reactions 1 was a case of leprosy, 1 of scarlatina (of 73 examined), and 3 of narcotised patients (of 60 examined).

In this country Bassett Smith, Fibbs and McIntosh, L. W. Harrison and Browning and Mackenzie have published series of results which in the main confirm those of Boas. Thus Bassett Smith (1909) analysed 1116 blood reactions with the following results:

	No. of Cases	Positive Reactions	Negative Reactions	% of Positive Reactions
Primary syphilis	183	139	44	75·9 %
Secondary syphilis early	407	384	23	94·3
Secondary late and tertiary syphilis	51	47	3	94
Congenital syphilis	1	1	0	100
Latent syphilis	39	18	21	46
Tabes and general paralysis	40	38	2	95
Chancroids	280	0	280	0
Gonorrhœa	39	0	39	0
Other diseases	140	2	124	1·3

Of the 2 cases among the non-syphilitic which reacted positively one was a case of scarlet fever, the other malignant disease of the liver with great jaundice. In a later publication (1916) Bassett Smith (24) gives his final results as follows:

	Positive		*Negative*
Primary syphilis	74 %	Chancroids	100 %
Secondary syphilis	98	Gonorrhœa	100
Tertiary syphilis	89	Other diseases	97
Parasyphilis	90		

The other diseases which gave positive results were acute malaria, scarlet fever, trypanosomiasis, and kala-azar.

In a series of 489 sera from syphilitic soldiers L. W. Harrison (4) (1910) obtained the following results:

Primary	71·8 %	positive
Secondary	90	..
Tertiary	83·5	..
Early latent	56·6	..

Browning and Mackenzie (6) (1911) published the results on 101 cases from a wide variety of acute and chronic diseases where syphilis could in all probability be excluded. Only 1 gave a + reaction. It was a case diagnosed clinically as chronic phthisis: no tubercle bacilli could, however, be found in the sputum. The various conditions were classed as follows:

Acute tuberculosis	6
Chronic tuberculosis	5
Malignant disease	5
Lobar pneumonia	4
Bronchopneumonia	5
Enteric fever	14
Typhus fever	14
Scarlet fever (various stages)	32
Cerebro-spinal meningitis	3
Eclampsia	1
Surgical cases	6

In an elaborate paper on the Wassermann reaction and its application to nemology, Fildes and McIntosh (7) published the results obtained on 372 cases which, unknown to them, were diagnosed as "clinically certain" syphilis by Dr. J. H. Sequeira Dermatologist to the London Hospital. Their results appear to show that with an improved technique the specificity of the Wassermann reaction is almost absolute in cases of syphilis.

	No. of Cases	*Positive W. R.*	*Negative W. R.*	*% of Positive Reactions*
Primary syphilis	33	31	2	93·9 %
Secondary syphilis	109	108	1	99
Tertiary syphilis	195	190	5	97
Congenital syphilis	35	35	0	100
	372	364	8	97·8

In 1913 the well-known serologist, Rudolf Müller (9), assistant for years in the Serodiagnostic department of Finger's great institute for syphilology and dermatology in Vienna, published a *résumé* of the results he had obtained in the examination of sera from 70,000 patients. From these results the following figures have been extracted. These are of importance not only from their number, but also from the fact that the examinations were carried out by one well qualified for the task.

In over 2000 healthy persons in whom every possible care was taken to eliminate syphilis, only 1 gave a positive Wassermann reaction. Müller believed that this solitary instance was one of latent syphilis that had escaped detection.

In 5000 cases of diverse diseases other than syphilis, and mostly severe in character, 220 = 4·4 % gave an incomplete positive reaction. In 100 of these, however, subsequent examination indicated evidence or suspicion of syphilis, leaving 120 cases (*ca.* 2·4 %) unaccounted for. In diseases other than syphilis Müller found complete positive reactions only in certain protozoal infections and in leprosy.

Passing to undoubted syphilitic cases his results were as follows:

Primary syphilis, 1320 cases, comprising		
Complete positive reactions	500	58·1 %
Incomplete positive reactions	280	
Negative reactions	540	41·9 %
Secondary syphilis, 3500 cases, comprising		
Complete positive reactions	**3300**	**= 94·3 %**
Medium to almost complete positive reactions	125	= 3·6 %
Slightly positive reactions	**53**	**= 1·5 %**
Negative reactions	22	= 0·6 %
Tertiary syphilis, 510 cases		
Complete positive reactions	482	= 94·5 %
Medium to almost complete positive reactions	20	= 3·9 %
Slight positive reactions	5	= 1·0 %
Negative reactions	3	= 0·6 %

Among these tertiary lesions there were 468 cases of tabes dorsalis, of which 284 (60·7 %) gave a complete positive reaction, and 386 instances of general paralysis of the insane with 376 (97·4 %) complete positive reactions.

Latent syphilis, 11,500 cases, with the following results:

	No. of Cases	*Complete positive W. R.*		*Incomplete positive W. R.*		*Negative W. R.*	
Latent syphilis	11500	2780	24 %	2520	21·9 %	6200	54 %
Early latent syphilis	4600	2180	47·4 %	980	21·3 %	1440	31·3 %
Late latent syphilis	1800	864	48 %	816	45·7 %	120	6·5 %

Working in the laboratory of the Army Medical School, Washington, D.C., Craig (17) has published (1915) the analyses of 18,000 Wassermann tests made by himself. His experience has been much the same as that of the authors just quoted. Among 9043 individuals either normal or suffering from diseases other than syphilis positive Wassermann reactions were found only 21 times (0.4 per cent.). In 4 cases the diagnosis was malaria in 3 tuberculosis, although 2 of these ultimately give a clinical history of syphilis; in 3 the diagnosis was psoriasis buccalis and in the remaining case a diagnosis was not established at all. A single Wassermann test on each of 4058 cases diagnosed as syphilis yielded the following results:

		Positive	Negative	Per cent. positive
Primary	908	813	95	89.5
Secondary	1189	1117	72	93.9
Tertiary	638	558	80	87.4
Latent	1215	1126	89	92.6
Congenital	28	25	3	89.2
Parasyphilis	22	15	7	68.1
	4058	3654	404	90.2

From his experience Craig concluded that if the diseases other than syphilis which occasionally give a positive Wassermann reaction can be excluded a "double plus" (++ = a distinct inhibition of haemolysis) is diagnostic of syphilis and the reaction is absolutely specific whether symptoms are present or not and whether there is or is not a history of syphilis. Under the same conditions a "plus reaction" (+ = at least 50 per cent. of haemolysis) may in primary, tertiary, or latent infections be interpreted as diagnostic, provided there is a clear history of infection or the presence of clinical symptoms. In the absence of either history or suspicious symptoms a + reaction should never be considered as diagnostic.

A diagnosis of syphilis should never be made on a "plus minus" reaction (± = less than 50 per cent. of haemolysis). Many normal individuals give such a reaction and it is of no value whatever as a diagnostic sign of syphilis.

Craig also considers that a single negative reaction (− = 0) has no value in excluding syphilis. Even the most severe secondary cases occasionally give such a reaction. It is only when a negative reaction is repeatedly obtained over a long period that it can be considered as good evidence of the disappearance of the disease, and in all such cases the result of the test upon the cerebrospinal fluid, a luetin test and a provocative Wassermann test should be made if one desires to be sure of the absence of syphilis.

Bulman (27) (1916) examined 288 cases in which there was no evidence of syphilis. They were classified in three groups: 1. skin diseases, 2. tumours, 3. miscellaneous.

		No.	Negative	Positive
Group 1.	Dermatoses	8	8	0
	Scabies	13	13	0
	Pemphigus	5	5	0
	Eczema	28	28	0
		54	54	0

		No.	Negative	Positive	Weak Positive
Group 2.	Sarcoma	12	12	0	0
	Malignant adenoma	15	15	0	0
	Glioma of brain	2	2	0	0
	Carcinoma	107	96	9	2
		136	125	9	2

		No.	Negative	Positive
Group 3.	Trichinosis	3	3	0
	Pernicious anæmia	4	4	0
	Hodgkin's disease	3	3	0
	Spasmodic chest	3	3	0
	Scarlet fever	15	15	0
	Lepra	6	3	3
	Tubercle	35	33	2*
	Malaria	10	10	0
	Arthritis	6	6	0
	Meningitis	10	10	0
	Streptococcal infections	4	4	0
		99	94	5

* These two positive cases ultimately gave a definite history of syphilis.

All these figures show that in the hands of trustworthy workers *a positive reaction is indicative of syphilis with exceedingly few exceptions*. The well-known fact that there may be no symptoms of syphilis in undoubted instances of the disease while the Wassermann reaction is positive is a point of great importance in estimating the value of the reaction. It also explains why a certain number of positive reactions may be obtained either in persons believed to be normal or suffering from conditions other than syphilis. Examinations of cases like these have been utilized to determine the incidence of syphilis in the general population. Such determinations are fallacious in that the 'population' is not general, but selected—usually a hospital population. Thus Fildes (290) performed 1002 Wassermann tests on persons of nineteen years and upwards, who visited the London Hospital for reasons wholly unconnected with syphilis. These reasons were fractures, wounds, diseases of teeth, cancer, hernia, and varicose veins. All medical diseases were excluded. In certain of the cases which yielded a positive reaction Fildes attempted to extract an admission of syphilis, but ultimately found that the inquiry was resented. In the first eight cases giving a positive reaction there was, however, a definite history of syphilis in three. One denied syphilis, and the remaining four were not seen a second time after the specimen of blood had been examined. Fildes' results showed that out of 1002 sera tested 84 were positive = 8·3 per cent. The series was composed of 646 males with 64 positive = 10·3 per cent., and 386 females with 20 positive = 5·1 per cent. If from the London Hospital 'population' 197 aliens with 13 positives be excluded, there remain 805 British cases with 71 positive results = 8·8 per cent. Grouping the cases in decennial age groups, and on the assumption of the specificity of the Wassermann reaction, Professor Karl Pearson, who analysed the figures, concluded that in the particular population examined 8 to 12 per cent. of the males, and 3 to 7 per cent. of females

had syphilis. In Fildes' series no general attempt was made to elicit a history of syphilis. Ehrlich (25) (1916) in Charlottenburg (Berlin) has examined 1800 cases of patients attending a skin-disease hospital. All were investigated for a history or for signs of syphilis and the cases were chosen where this could so far as possible be excluded. His results were as follows:

	Males		Females	
Age	No. of cases examined	No. of Syphilitics	No. of cases examined	No. of Syphilitics
16–20	96	1	145	9
21–30	603	1	313	39
31–40	215	9	64	11
41–50	48	3	26	4
Not 50	30	1	18	2
	1234	15 = 1·5 %	566	65 = 11·5 %

Of the 18 males 12 had no other sign but a + W. R., while 6 had some other suspicious sign. In 6 there was a history of a sore which had been alleged not to be syphilitic. Of the 566 females a number were of the lower and prostitute class. In 132 women and girls where there was no suspicion only 2 = 1·5 % reacted positively.

It has been asserted by some writers that a single Wassermann test is not of value, and should not be used as a basis for the diagnosis of the disease. The value of first diagnostic Wassermann tests has been made the subject of inquiry for the purposes of this report by Staff Surgeons P. Fildes and R. J. G. Parnell on 1414 men admitted to the Royal Naval Hospital, Haslar for syphilis or suspected syphilis.

The material was unselected, every man being included who was admitted between certain dates (except a few who by mistake were not tested or were otherwise unsuitable).

The cases were admitted in all stages of treatment. They were not fresh untreated cases, such as are usually met with in a civil hospital. There was a preponderance of early cases.

Of the 1414 men 1157 (81·8 per cent.) gave positive reactions and 257 (18·1 per cent.) negative.

The evidence of syphilis in the positive cases was as follows:

a. 938 men were conclusively shown to be syphilitic by reason of the presence of *S. pallidum* or clinical signs or histories of a generalized condition characteristic of syphilis.

b. 62 men were accepted as syphilitic on the evidence of anti-syphilitic treatment having been applied previously for local lesions which in the opinion of the medical officer responsible for treatment were syphilitic.

c. 16 were shown to be syphilitic by means of lumbar puncture and ophthalmological examination.

d. 5 were shown to be syphilitic by methods *b* and *c* combined.

e. 61 were accepted as syphilitic by reason of previous or subsequent positive Wassermann reactions.

f. 4 men were diagnosed by methods *c* and *e*.

g. 3 men were diagnosed by methods *b* and *e*.
h. 3 men were diagnosed by methods *b*, *c*, and *e*.
i. 65 men remained with positive reactions, but no direct evidence of syphilis was obtainable. Practically all were suffering from venereal conditions.

The evidence of syphilis in cases giving a negative Wassermann reaction was:

a. 127 men had sores in which S. pallidum was found.
b. 34 men had no lesions, but S. pallidum had been found in sores now healing or recently healed
c. 5 men had sores in which S. pallidum could not be found, but they nevertheless developed syphilis.
d. 1 man had manifest secondary syphilis.
e. 2 men had manifest tertiary syphilis.
f. 2 men had cerebro-spinal syphilis.
g. 10 men had no lesions, but more or less undoubted histories of syphilis.

In the remaining 76 cases there was no evidence of syphilis. They included the following groups:

23 men had sores which were untreated, and yet they did not develop syphilis.
45 men had sores in which S. pallidum could not be found. They were untreated, but did not come again under examination.
2 men were said to have had syphilis, but there was no evidence of this.
6 men had been diagnosed as syphilis on insufficient grounds by outside practitioners

With regard to the incidence of positive Wassermann reactions in different periods of the disease the following figures were made out. Of a total of 1338 cases of syphilis

166 were in the primary stage before the W. R. had become positive.
445 primary cases (= 72·7 per cent.) gave a positive W. R., but there were no other signs or history of general infection except glandular enlargement up to and including 18 months from infection.
473 cases of syphilis with signs or history of general infection up to and including 18 months from infection. This group included chiefly early secondary but also some latent and early tertiary cases. One of the secondary cases gave a negative reaction. In this group the percentage of positive reactions was therefore 99·7 per cent..
363 cases of late secondary, tertiary, or latent syphilis over 18 months from infection. Of these, 2 cases of tertiary, 2 cases of cerebro-spinal, and 10 cases of 'latent' (possibly cured) syphilis gave negative reactions, making a total of 94·7 per cent. of positive reactions in this group.

These results show that a single Wassermann test under the conditions stated possesses a high diagnostic value.

A usual procedure of determining the accuracy of a clinical method of diagnosis is to verify such a diagnosis by post-mortem examination. It is a matter for surprise that, in spite of the fact that vast numbers of cases have been examined by the Wassermann reaction during life, there exist but few series of published cases where the results of Wassermann findings have been analysed in the light of a subsequent autopsy carefully carried out. With a view to obtaining some knowledge on this highly important side of the question Dr. H. M. Turnbull, Pathologist to the London Hospital, undertook to analyse his post-mortem records and has communicated the results to the Committee. These results which will subsequently be published in detail, concern especially the value of the Wassermann reaction in sera obtained after death. There occur, however, a number of cases in which the Wassermann test was carried out during life in patients who subsequently died and were subjected to post-mortem examination. We have selected one such series of cases in which the test was made with heart-cholesterin antigen as described by Fibbs and McIntosh, who actually carried out the examination of the sera. No selection of the cases was made, the list including all the examinations of the kind made in the London Hospital up to 1916. The autopsies were carried out by Dr. Turnbull as completely as possible, and numbered 98, of which 54 comprised the body only, while the remaining 44 comprised complete examinations of body and head.

Without at present including all the details accumulated by Dr. Turnbull, it suffices to state that his ultimate conclusion was that there was no proof that the test was inaccurate in 94 out of these 98, in 88 indeed the post-mortem result and the Wassermann test were in complete agreement, both being negative 50 times and both positive 38 times.

In 6 cases syphilitic lesions were not detected, although the serum gave a positive reaction. The presence of a syphilitic infection could however not be excluded. In 1 case an infant, the histological evidence appeared to have excluded a syphilitic infection'; the parents were proved to be syphilitic.

There remain therefore only 3 cases out of the 98 in which the autopsy threw doubt on the accuracy of the test. In 1 case the Wassermann reaction was negative in the serum (2 ante-mortem and 1 post mortem tests) in the presence of a lesion of the spinal meninges and cord, which was in all probability syphilitic and apparently still active. In the second case the reaction was negative in the serum in the presence of three lesions, one syphilitic (aortitis), one probably syphilitic (glossitis), and the other possibly syphilitic (fibrosis of testicle). According to the histological examination the specific inflammations were almost completely if not completely, inactive. In the third case an active chronic syphilitic encephalitis was associated with a negative reaction in the serum. These results demonstrate the almost deadly accuracy of the Wassermann test when properly carried out, for in only 3 per cent. of the cases were there inaccuracies in the sense that syphilis was not diagnosed during life, although certainly or probably present. In the remaining 96·9 per cent.

of the cases the most searching inquiry failed to show that the diagnosis made during life was at fault.

Criticisms of the Value of the Test.

In spite of the fact that the accuracy of the Wassermann test has been established in an unusually large series of observations, a number of criticisms have been raised. In part, these appear as mere statements that it is inaccurate, or a few isolated observations have led certain writers to condemn the test altogether. In a few instances the indictment is much more formidable, inasmuch as serious discrepancies are alleged to have occurred where one and the same serum has been tested by different serologists. Thus Wolbarst (11) quotes the case of a young man who had no symptoms of syphilis with the exception of a suspicious throat lesion some years previously. His blood was sent to two laboratories. A returned a negative result, B a 4+result. A second sample of blood taken three days later was divided into three portions, of which one was sent to A, and two were sent to B. The report of A was 'negative'; the report of B was 1+. Wolbarst quotes the following result of eleven other cases, in which one and the same serum was tested by two different serologists:

	Serologist	Serologist	Clinical findings
1.	A = +	B = —	not syphilis
2.	A = +	B = —	" "
3.	A = +	B = —	" "
4.	A = +	C = —	" "
5.	C = +	E = —	syphilis
6.	A = +	A = ?	not syphilis
7.	A = +	A = ?	syphilis
8.	A = —	A = ?	"
9.	A = —	A = ?	not syphilis
10.	A = —	A = ?	" "
11.	C = —	A = ?	" "

From results like these Wolbarst concluded that it was a gross error to accept the findings of one serologist as conclusive, particularly if the result is positive and the diagnosis dependent on his work. He also quotes without details the results of 37 other cases studied for discrepancies:

Agreement between the serologists took place in 25 = 70 per cent.		
Complete contradiction	ditto	5 = 14 per cent.
Slight disagreement	ditto	6 = 16 per cent.

In a later paper (22) he comments on the results of 85 examinations of sera, where three examples taken at one and the same time were submitted with a few hours delay to three different serologists of experience and reputation. The results were:

Serologist	[illegible] positive	[illegible] positive
A	53	27
B	28	57
C	56	29

In the 33 cases in which absolute contradictions were reported

It is noted that serologist A used the Wassermann technique except that the quantities were reduced to one-tenth of the original and the titration was carried out by the two-tube test for four units. E and C used the Wassermann as described by Citron.

In 1914 Phelps (18) published a preliminary report of Wassermann tests conveniently performed in four laboratories although no data are given respecting either the methods employed or the degree of discrepancy.

Four laboratories tested each of 110 sera; the results agreed in 68 instances = 60.8 per cent, and disagreed in 43 = 39.2 per cent.
Three laboratories tested each of 135 sera; the results agreed in 70 instances = 51.9 per cent, and disagreed in 65 = 48.1 per cent.
Two laboratories tested each of 110 sera; the results agreed in 72 instances = 65 per cent, and disagreed in 38 = 34 per cent.

Ellis and Meakinney (21) (1915) carried out in detail an interesting investigation along the same lines. Sera were submitted under identical conditions from about 900 patients, and they were at least examined by two serologists, and later by three more. These serologists were all connected with teaching institutions and hospitals. They are distinguished in the following by the letters A, B, C, D, E, F, and G. Of these all with the exception of E and F submitted 1 report. E submitted 2 reports with 2 different antigens, these were labelled E_1 and E_2. F, using these different antigens, submitted three reports which were labelled F_1, F_2, and F. while G, using these different antigens submitted a majority report.

Blood was collected from 95 normal pregnant women denied syphilis from 70 private or hospital patients suffering from diseases other than syphilis, and from 186 patients suffering from different forms of syphilis. All these cases were under the personal observation of the authors and the Wassermann reaction had been tested before the special inquiry was begun. In the syphilitic cases a clinical expression of "positive", "negative", or "doubtful" was submitted before the specimen was submitted, and of the findings the serologist was not informed. The clinical expression was based on a personal knowledge of the case, the type and activity of treatment, and the results of previous Wassermann tests. Where two or more specimens were sent from the same patient at the same time different names were used. The test was therefore carried out under entirely objective conditions.

In the group of 25 normal persons 27 series of tests were carried out, with no less than 5 reports in each series. All the serologists agreed in a negative report in 21 series and disagreed in 6. In each instance of disagreement, a positive report was not submitted by more than one laboratory. In 2 cases in which the tests were repeated, one serologist reported in one case first a + then a −, while in a second case, another serologist reported first a − and then a +.

On 70 persons suffering from conditions other than syphilis, 74 tests were made. In 4 of these the reports varied considerably, two or more positive results being obtained by different serologists in each case. The serum of one of these was examined four times, with the following interesting result:

1st examination	4 positive reports	0 negative report
12 days later	3 „ „	2 „ „
Next day	5 „ „	1 „ „
6 weeks from 1st examination	2 „ „	4 „ „

On account of the numerous positive reactions this patient was repeatedly questioned about a possible syphilitic infection, but denied it. The luetin test was negative. Examining in detail the Wassermann results carried out on this patient it was found that

Laboratory	E gave successively + reports
„	A „ 3 + and 3 − „
„	B „ 2 + and 1 − „
„	C „ 2 + and 1 − „
„	D „ 1 +, then −, then +, and finally −

The blood of a second patient examined in a similar manner showed

at first examination 4 negative and 1 positive result;
at second „ 6 „ „ 2 „ results.

In a third patient there were 4 positives and 2 negatives; while in a fourth patient there were 6 positives, 2 negatives, 1 doubtful, and 1 anti-complementary report. This patient was referred to a neurologist with the diagnosis of cerebral tumour. The cerebro-spinal fluid yielded 9 negative and 1 positive reaction in the hands of different serologists.

Of the remaining 66 patients whose sera were examined only once, all serologists agreed in a negative report 56 times. In 10 cases one serologist disagreed with the others in submitting a positive report.

In the group of 197 cases of syphilis in all stages 40 series of tests were made on 26 patients the subjects of the primary, secondary, or tertiary stages of the disease. All the serologists agreed in a positive reaction in 25, and disagreed in 15 cases. With no exception there was only 1 negative report in each of the tests which disagreed. This was a patient with a nodular syphilide of the leg, who responded to anti-syphilitic treatment. Of the remaining 14 tests which differed a repetition was carried out in 4. In each case the second test gave a + report by the serologist who at the first had reported a negative reaction.

Syphilis of the eye and nervous system gave very discordant results. Thus in a series of 41 tests there were 28 disagreements.

108 examinations were carried out on 88 persons who were known to have had syphilis but at the time had no manifestations. Many of them had been treated. Repeated examinations were carried out on 16 of these, 13 having 2, 2 having 3 and 1 having 4 examinations. In this series Uhle and Mackinney found the results so inconsistent both from the same and from different laboratories that they scarcely admitted of analysis.

With regard to the technique employed, it is stated that four of the serologists used a specific antigen, one used 2 separate cholesterin antigens, while one used 2 cholesterin antigens and 1 specific antigen, i. e. 3 in all.

Uhle and Mackinney set out their figures in the following tables which, however, are not very lucid:

TABLE I.—NORMAL AND NON-SYPHILITIC CASES.

Case No.	Laboratory	Number of tests	Length of time	Antigen employed	+	±	−	Total number of tests	Percentage of positives
103	A	2	2	c	5	3	3	11	71.4
97	B	11	c	2	1	2	1	6	66.7
64	C	2	2	1	2	1	1	4	50
97	D	11	2	2	10	3	1	14	71.4
67	E	10	2	c	9	2	1	12	75

Of the latter, 20 per cent. varied in 1 test, 30 per cent. in 2 tests, 12 per cent. in 3 tests, and 8 per cent. in 4 tests. In other words, if a specimen of blood from the same individual be submitted to 10 tests by different serologists there is 1 chance in 5 that the tests will agree.'

TABLE III. COMPARISON OF 168 TESTS REPORTED BY LABORATORIES A, B, C, D, E_1, AND F_2.

168	A	98	13	6	8	7	2	40	33
168	B	113	0	7	9	5	5	29	28
168	C	124	2	1	3	20	4	13	54
168	D	59	0	2	23	3	15	76	72
168	E_1	96	3	0	7	3	1	44	44
168	F_2	91	3	0	0	16	10	45	42

An analysis shows that all laboratories agree in their findings in 47 per cent. They vary in one result in 20 per cent., in 2 results in 12 per cent., and in more than 2 results in 21 per cent.

Uhle and Mackinney conclude their investigation by remarking that the results of the Wassermann test are disappointing. 'When', they say, 'we find that various representative serologists report positive findings in from 2 to 18 per cent. of normal individuals and that in active syphilis in which the clinical diagnosis is certain some serologists report only 50 per cent. of positive results there is every reason to discredit the diagnostic value of the test. In suspected latent syphilis, and in syphilis under active treatment, the most extreme variations occur, and in these conditions in which the clinician needs its help the most, it is the least accurate.

Very different conclusions were reached in 1916 by Simons, Jones and Goddard (34) as the result of a combined investigation carried out on 1000 specimens, viz. 981 sera and 19 cerebro-spinal fluids. These specimens were examined simultaneously by Simons and Jones in the Bacteriological Laboratory of the Vanderbilt University (Nashville, Tenn.) and by Goddard in the Laboratories of the Board of Health of the State of Tennessee. The latter used as antigen an acetone insoluble fraction of the lipoids of beef heart (Noguchi's antigen); Simons and Jones used a similar antigen for the first 535 tests and Coca and L'Esperance's antigen for the remaining 465 tests. The general agreement in the two series of tests was very striking.

Board of Health, Tenn.	1000	218	21.8
Vanderbilt University	1000	224	22.4

The specimens were also divided into three series as follows

TABLE I.—RESULTS OBTAINED IN 1000 WASSERMANN TESTS WHEN EACH LABORATORY USED ITS OWN REAGENTS.

Series I	411	92·2	13	3·1	18	4·3
" II	267	94·0	11	4·0	6	2·1
" III	145	93·8	5	3·1	14	8·9
	935	93·5 %	30		35	

TABLE II.—RESULTS OBTAINED IN 628 WASSERMANN TESTS WHEN FOUR LABORATORIES USED THE ANTIGEN SUPPLIED BY THE BOARD OF HEALTH.

Series II	267	94·0	11	4·0	6	2·1
" III	121	91·7	5	3·8	11	8·3
	388	93·4	16		17	

TABLE III.—RESULTS OBTAINED IN 628 WASSERMANN TESTS WHEN FOUR LABORATORIES USED THE ANTIGEN SUPPLIED BY THE VANDERBILT UNIVERSITY.

Series II	267	94·0	11	4·0	6	2·1
" III	145	93·8	5	3·1	14	8·9
	412	93·9	16		20	

From these results Simon Jones and Goddard concluded that when the reactions are carried out with proper technique by two laboratories a very high percentage of agreements should be reached. In their series it was 93·5 % in 1000 tests. The divergences which amounted to 6·5 % are due to the difficulty in the standardization of the sheep blood, complement and ambroceptor, inasmuch as higher results were obtained when both laboratories used the same reagents (compare results in Table I of Series I and Series III). More of this error was eliminated when in addition to this the same antigen was used by both laboratories (compare the results of Series III in Tables I, II and III).

The paper of Ulle and Mackinney created a great deal of interest in America and was followed by a number of communications, mostly of minor importance, in which the discrepancies in Wassermann results were emphasized. Both investigators and clinicians took part in the discussion, as the result of which Dr. Hayes Emerson, deputy commissioner of health of New York City, announced a committee to consider the whole question of the

reliability of the Wassermann reaction, and to attempt to standardize the technique. The committee, composed of professional serologists in the leading medical institutions in New York, held many meetings, but its work was not completed. Apparently the chief difficulty was that, although no two members agreed precisely in the technique of any single step in the reaction, each considered that he was working along classic principles with a technique which he regarded as efficient. With the exception of Coca, all the other members of the committee considered that in the vast majority of cases the Wassermann reaction is reliable, and, with a few well-known and easily-excluded exceptions, is diagnostic of syphilis; that most of the few instances in which contradictory reports were received from different serologists were actually cases of syphilis showing weak reactions detectable by certain forms of technique, but not by others, and that when all precautions are taken false positive reactions are avoidable. In the last two or three years a number of publications have appeared in the United States commenting on the complexity of the test, and emphasizing the necessity for standardization, but up to the present time no one method has been considered to be the standard one.

In Great Britain the reports of discrepancies in the Wassermann tests led to a similar state of affairs, and the Medical Research Committee appointed a Standards Sub-committee, which after much deliberation issued a report (Special Report Series, No. 14, 1918) in which three methods were recognized as conforming more or less closely to the condition of a 'standard' in the present state of knowledge. Whether the criticism of the Wassermann test as performed in England is general or not is not known, but so far very little that is of value on the subject has been published.

The study of German medical literature during the war has revealed that similar doubts as to the reliability of the Wassermann reaction have been the subject of discussion. Even in 1910 Freudenberg (2) published a warning on the unreliability of the Wassermann test and quoted two cases in support of his contention. In one the serum of a man who had had syphilis was examined on three different dates by one or more of four different serologists as follows:

Date	*A*	*B*	*C*	*D*
Jan. 19, 1909	–			
April 2, 1909		+		
Nov. 11, 1909		+	+	–

In the other, who had a sore on the penis, in which, however, no spirochaetes were found, the results were equally discordant:

Date	*B*	*C*	*D*	*E*
Oct. 26, 1909	+			
Oct. 29, 1909		–		
Nov. 4, 1909	+	+	–	

In the same year Saalfeld, having had a like experience, proposed in the Berlin Medical Society that some sort of standardization should be carried out under State control in order to lessen, if possible, the divergent results. His proposal was not accepted.

In 1916 33] he returned to the subject and cited three cases in which discordant results were returned. In one case one serologist returned a serum as '+ +', another as '−', and still another said the result was + in active but − in inactivated serum. In the second case one laboratory returned the result as + + + +, two others as −, while a fourth gave + in active and − in inactive serum. In the third case one laboratory gave a 4+ result two others a −.

Freudenberg (34), 1916 who had also been continuing his observations recorded the results in 144 sera examined by two or more serologists simultaneously. Altogether twelve different persons carried out the tests, which were entirely objective. The results were as follows:

In 1 cases where 4 serologists tested each serum differences were obtained
3 times = 75 per cent.
In 44 cases where 3 serologists tested each serum differences were obtained
26 times = 59·1 per cent.
In 99 cases where 2 serologists tested each serum differences were obtained
14 times = 14·2 per cent.

These divergences were not slight, as e.g. between + and ±, or − and ±, but were mostly complete contradictions as, e.g. + versus −.

In six years Freudenberg emphasized the fact that there had been no real improvement in the results because analysed from a chronological standpoint, the percentage of divergences remained practically constant. Thus, dividing the 144 sera into 4 quarters as regards the dates of examination, he found—

1st quarter	36 tests with	12 divergences	= 33 per cent.
2nd „	36 „	„	12	„	= 33 per cent.
3rd „	36 „	„	10	„	= 27·8 per cent.
4th „	36 „	„	12	„	= 33·4 per cent.

Heller (32), 1916, who was in charge of the venereal department of a military hospital, had sera to the number of 87 tested in two well-known laboratories, viz. that of Prof. L. Pick and that of Ledermann. The following were the results obtained:

1. Cases in which identical results were returned = 36
2. Cases in which there was a difference in the interpretation of the result (e.g. weak + + = + + + +) = 5
3. Cases in which there were differences in the degree of reaction = 30
4. Cases in which directly contrary results were returned = 16

Of these 16 Ledermann had 10 negative, and Pick 6, while the Central Institute gave positive results. Heller considered that the Wassermann results break down exactly in the cases where help is most required, and he quotes a few instances in which the results were quite at variance with the clinical experiences and history. He believed that the fault lay not so much with the serologist as with inherent defects in the method employed to test the serum.

Wassermann himself here entered the lists and strongly and adversely criticized the publications of Heller, Freudenberg, and Seelfeld and was particularly indignant at their suggestion that the Wassermann reaction is untrustworthy because different results were obtained when one and the same serum was tested by different

serologists. These divergent results had been used both in the medical and lay press to discredit the test. In order to clear the matter up Wassermann (56) suggested a combined test by two different workers in two reputable institutes, viz. Dr. Mohrmann in the Kaiser Wilhelm Institut für Experimentelle Therapie and Dr. Lange in the Kaiser Wilhelm Akademie für das militärärztliche Bildungswesen. Wassermann stipulated that all sera giving an absolute or almost absolute inhibition of haemolysis (+ + + + ; + + +) were to be returned as 'positive', whereas all sera which showed complete haemolysis were to be returned as 'negative'. All sera between these limits of haemolysis (such degrees as + + ; +) were to be returned as 'doubtful'. The sera were collected by Heller, who transmitted them to Prof. Bickel, who then sent them numbered to the two testers. Of 50 sera tested in this way 48 showed complete harmony in the results. Of the remaining two, one was returned as 'negative' by one observer and 'doubtful' by the other, the remaining serum as 'positive' by one observer and 'doubtful' by the other. In these results Wassermann saw a complete confirmation of his view that in the hands of trustworthy workers the Wassermann test is extraordinarily accurate. In his reply Freudenberg (51) draws attention to the frequence of 'doubtful' reactions in the diagnosis of syphilis, and the difficulty in determining the significance of reactions returned as ±. In Wassermann's series of 50 sera tested by two independent observers, the one found 'doubtful' reactions six times, the other eight times = 14 per cent., which was seven times as large as the 'doubtful' sera tested by G. Meier in another series. Freudenberg also repudiated Wassermann's suggestion that divergence of result is largely due to the personal equation of different observers or defective technique, and he now published the names of twelve serologists whose results had been divergent. Some of these were widely known for their special work in connexion with the Wassermann test, and in some cases had been actual pupils of Wassermann himself. Freudenberg then analysed the results where one tester had been opposed by a number of others in examining the same sera, and estimated the number of times that harmony (=) and divergence (≠) was noted. Thus a well-known serologist, Dr. Georg Meier (B), examined a number of sera (72), which were examined at the same time by nine others (A, C, D, E, F, G, H, I, L) with the following results:

Observers	Number of sera	=	≠	+	−	±	+	−	±	+	−	±
B : A	48	24	4				12	1				
B : C	4	3	2				3					
B : D	9	3	3				3			3		
B : E	4	3	1				4					
B : F	1	—	1									
B : G	1	1										
B : H	2	1	1	1								
B : I	1	1	—	1								
B : L	1	1	—									
Combinations	72	49	23	2			22	1		3		

From the table it is seen that "B" [Dr Georg Meier] who opposed to 9 other testers agreed completely in his results with only 2 of them, and in one case only 1 serum was tested (B : L). In other partnerships it is seen that he differed 14 times in 38 tests.

In another series Dr Hermann Mayer (L) was pitted against six other serologists in a test of 63 sera with the following results:

Opponents	Number of Sera	Results		Divergences (+)							
		+	−	−	±	±	−	−	+	±	− +
L : A	33	28	1	3					1		
L : B	1	1	—								
L : D	1	—	1						—		
L : G	9	3	5	1							
L : I	13	12	1	1							
L : M	2	2	2	—					—		
6 combinations	63	47	11	5					1		

Here it will be seen that complete agreement was attained with one opponent only, and it is not certain that only 1 serum was the subject of the test. In the case of another opponent 11 divergences were recorded in the case of 33 sera tested. Fraenkelberg writes at considerable length on the value of these comparative tests and repudiates the idea that the disparity is due to the testers alone. He refers it much more to variations in the test material, especially the antigen, and he cites a result obtained by G. Meier (of the date Sept. 1910) who with 2 Alcoholic extracts found a − result, with a watery extract a ±, and with still another extract tested on the following day a complete positive result viz. + + + + + The case was some disorder of micturition on a doubtful luetic spinal basis.

He also considers that part of the divergence is attributable to certain sera rather than others: a disparity once observed was very apt to recur again and again in the reports of different testers. He publishes a table of one such serum as follows the case being stated to be undoubted syphilis:

Date	A. Meier	G. Meier	Kraus	Lange	Mayer	Meier	Weil	Wolff-Eisner
Dec. 19, 1908	weak +							
May 15, 1910	+							
June 22, 1912	weak +	−						+
Jan. 31, 1913	strongly +	+						+
Jan. 29, 1913	..	−		−		weak +		<
July 16, 1913	+	—		−		−		+
July 19, 1913	+	−	weak +			−		<
July 6, 1909	—		—		weak +			+

Hermann Mayer (58) criticises the reasoning of Fraenkelberg and points out the fallacy of comparing 38 sera on the one hand with

l serum on the other. He also points out that Freudenberg has eliminated the almost complete harmony of certain of the testers while he emphasizes the discordant results of others. The want of uniformity, especially in the series in which tester A collaborated, is attributed to the use of heart extract instead of liver extracts, and he considers that as a diagnostic agent the Wassermann reaction gives wonderfully accurate and almost constant results. This is, however, denied by Freudenberg (59).

Heller (52) also replied to Wassermann's criticism, and published a complete list of the fifty cases referred to by Wassermann. In addition to the two tests made in Lange's and Wassermann's laboratories he had taken the precaution to have a third portion of each serum tested in another laboratory X, the tests being carried out by a well-known expert. Of the 50 sera 48 were tested by all three examiners. The general results were as follows:

Complete agreement	22 cases	=	46 per cent.
Differences	26 ,,	=	54 per cent.
Complete contrary results	9 ,,	=	19 per cent.
Considerable differences	3 ,,	=	6 per cent.
Slight differences	14 ,,	=	29 per cent.

In the table it will be seen that the comparative serological results are given, the clinical diagnosis by Heller or others and the estimate which of the three serological tests agreed best with the clinical facts.

20	.. ..			neg.	neg.	pos.	! ! !	X
21	.. ..			neg.	neg.	pos.	! ! !	X
22	.. ..			neg.	neg.	doubtful	! !	X
23	Syphilis			pos.	pos.	pos.	+	
24	..	I pos. III doubtful	II neg.	neg.	neg.	neg.		
25	Not syphilis			neg.	neg.	neg.		
26	Syphilis cure fancied			neg.	neg.	anti-complementary	!	
27	.. .. ..			neg.	neg.	doubtful		
28	.. .. ..			doubtful	doubtful	pos.	!	
29	Not syphilis	doubtful		neg.	neg.	pos.	! ! !	L. W.
30	Sclerosis			doubtful	doubtful	*not sheep*		
31	Lues			neg.	neg.	doubtful	!	
32	Chancre not syphilis			neg.	neg.	neg.		
33	.. ..			neg.	neg.	pos.	! ! !	L. W.
34	.. ..			neg.	neg.	doubtful	!	L. W.
35	Syphilis			pos.	pos.	pos.		
36	Clinically not syphilis	pos.	pos.	neg.	doubtful	doubtful	!	
37	Chancre			neg.	neg.	neg.		
38	Clinically not syphilis	pos.	pos.	pos.	pos.	doubtful	!	
39	Clinically not syphilis—said to have had S		pos.	pos.	doubtful	neg.	! ! !	
40	Chancre			doubtful	doubtful	neg.	!	
41	Cerebral syphilis ?			neg.	neg. *	doubtful slight +	? ?	
42	Chancre			neg.	neg	neg.		
43	Sclerosis			neg.	neg.	doubtful slight +	? ?	
44	Ul. phagad.			neg.	neg.	neg.		
45	Gonorrhœa, epilepsy, melæna	neg	neg	pos.	pos.	neg.	! ! !	+
46	Syphilis formerly			pos.	pos.	doubtful prob. +	!	
47	Syphilis			pos.	pos.	neg.	! ! !	L. W.
48	..			pos.	pos.	pos.		
49	Gonorrhœa			neg.	neg.	neg.		

* Probably an error, given in Wassermann's series as 'negative'.

REFERENCES.

All these papers have been consulted by the Author with the exception of those marked * which were unobtainable.

1. Bassen-Smith: The diagnosis of syphilis by the complement-fixation method. [illegible] Lond., 1919, II, 1414.

2. Bauduin: Essai Méthodique sur la Valeur de la Réaction de Wassermann dans la Syphilis. [illegible] 1911, **47**, 1241.

3. Gaspis et Lacomme: 200 cas de recherche de Wassermann. [illegible] 1910, **18**, 561.

4. Hazen, L. W.: A Study in Power and Mastery (System of Syphilis). London, 1919, VI, 179.

5. Wassermann: The diagnostic use of the complement fixation method. [illegible] Lond., 1910, II, 1127.

6. Browning and Mackenzie: Recent methods in the diagnosis and treatment of syphilis. London, Constable, 1911, pp. xxxv + 366.

7. Fildes and Mehrtens: The Wassermann reaction and its application to neurology. [illegible] Lond., 1913, **36**, 193.

8. Mayer, L. H.: The Wassermann reaction in the Johns Hopkins Hospital. [illegible] Balt., 1913, **24**, 135.

9. Meyer, Rudolf: Die Serodiagnose der Syphilis und ihre Bedeutung für Diagnose, Therapie und Prognose. Wien, 1915. 311 S.

10. Pusey: Unreliable Wassermann reactions. J. Am. M. Ass., Chicago, 1920, 61, 1920.

11. Wolfsohn: Contradictory findings in the Wassermann test. [illegible] 1913, **97**, 378.

12. Boas: Die Wassermannsche Reaktion und ihre Beziehungen [illegible] 2nd edit., Berlin, 1914.

13. Levaditi et Kritchevsky: Sensibilisatrices de la syphilis; spécificité de la réaction de Wassermann; sérums polyvalents. [illegible] Par., 1914, 15, **25**, 379.

14. Nicolas et Gaté: La réaction de Wassermann positive à elle seule [illegible] 39 p. 100 de recherches positives chez les non-syphilitiques. [illegible] Par., 1914, **25**, 209.

15. Sachard: Statistical notes on a series of 6000 Wassermann tests [illegible] performed in the Harvard Neuropath. testing laboratory, 1911. [illegible] 1914, **170**, 947.

16. Sicard, C. F.: Sources of error in the Wassermann technique. [illegible] 1914, **99**, 1242.

17. Craig, C. F.: The results and interpretations of the Wassermann test. [illegible] Phila., 1915, **149**, 41.

18. Phillips, O. P.: A preliminary report of the result of the Wassermann tests as reported from different laboratories. [illegible] 1915, **173**, 391.

19. Schlesinger, M. F.: Reasons for discrepancies in reports of the Wassermann reaction from a technician's side. [illegible] N. Y., 1915, **87**, 61.

20. Thomas, O. L.: Results of Wassermann test [illegible] at the Naval Prison, Portsmouth, N. H. [illegible], N. Y., 1915, **87**, 961.

21. Uhle and Mackenzie: Comparative results of the Wassermann test. [illegible] Chicago, 1915, **65**, 862.

22. Weichselbaum: A further statistical study of the contradictory findings in the Wassermann test. [illegible] St. Louis, 1915, **22**, 109; [illegible] N. Y., 1915, 11, 445.

23. Allen, A. H.: The diagnosis of syphilis by the Wassermann reaction. [illegible] Wash., 1916, **10**, 814.

24. Bassett Smith: The complement deviation (Wassermann's) reaction for syphilis and some comments on irregularities met with in practical experience. *J. Roy. Nav. M. Serv.*, Lond. 1916, **2**, 282.

25. Bruhns: Ueber unbewusste Spätsyphilis nebst Mitteilungen über Ausfall der Wassermannschen Reaktion an 1800 angeblich nicht mit Syphilis inficierten Menschen. *Berl. klin. Wchnschr.*, 1916, **53**, 833.

26. Bryan, W. M.: Prevalence of syphilis as indicated by the routine use of the Wassermann reaction. *Pub. Health Rep.*, Wash., 1916, **31**, 3239.

27. Buhman, R.: Specificity of the Wassermann reaction. *Tex. Med. Journ.*, San., 1916, **41**, 319.

28. Cole, A. F.: The clinical significance of the Wassermann test. *Brit. Journ. Ad.*, Balt. and Cambridge [Eng.], 1916, **1**, 484.

29. Fildes, P.: The prevalence of syphilis among apparently healthy adult inhabitants of the East End of London. Roy. Commission on Venereal Diseases. Final Report. 1916, App. XII, 139.

30. Fosbery, A. L.: The defects of Wassermann's reaction. *Canada, Lancet and Jour.*, Toronto, 1916, **41**, 155.

31. Friedenthal: Nochmals eine Mahnung zur Vorsicht bei der diagnostischen Verwertung der Wassermann Reaktion. *Berl. klin. Wchnschr.*, 1916, **53**, 1454.

32. Hetter: Kritisches zur modernen Syphilislehre. *Berl. klin. Wchnschr.*, 1916, **53**, 978.

33. Saalfeld: Zur Ausführung der Wassermannschen Reaktion in der Praxis. *Deutsche med. Wchnschr.*, Berl. u. Leipz., 1916, **42**, 1351.

34. Simons, Jones and Goddard: The margin of error in the Wassermann test a study of 1000 tests made independently by two laboratories. *Journ. Am. M. Ass.*, St. Louis, 1916, **23**, 654.

35. Smith and MacNeal: A comparative study of different methods of performing the Wassermann test for syphilis. *Journ. Am. Inj. Dis. and Med.*, N. Y., 1916-17, **14**, 7; also *Brit. Journ. Ad.*, Balt. and Cambridge [Eng.], 1916, **2**, 75.

36. Udd and Mackinney: A clinical study of the comparative results of the Wassermann reaction. *Boston M. and S. J.*, 1916, **174**, 55.

37. Udd and Mackinney: A further study of the comparative results of the Wassermann test. *Med. Journ.*, N. Y., 1916, **44**, 301.

38. Ball, C. R.: A consideration of the serodiagnostic reactions after five years of observation. *Journ. Am. M. Ass.*, Chicago, 1917, **68**, 262.

39. Brodsenbrenner and Schlesinger: Conclusions drawn from a comparative study of different methods of performing the Wassermann reaction. *N. York M. J.*, 1917, **106**, 489.

40. Clark and Nelson: The value of the Wassermann reaction in the diagnosis and treatment of syphilis. *Canada, Lancet and Jour.*, Toronto, 1917, **43**, 345.

41. Craig: The practical application of the Wassermann test in the diagnosis and control of treatment of syphilis. *Journ. Am. Inj. Dis.*, St. Louis, 1917, **1**, 192.

42. Darling, Georgina R.: The Wassermann test as a means of estimating the prevalence of syphilis in a community. *Indian J. M. Sc.*, 1917, **144**, 147.

43. East, C. R.: The Wassermann reaction. *Brit. M. J.*, Lond., 1917, **II**, 777.

44. Gebhardt: The diagnosis of syphilis from specimens sent to the laboratory. *Am. J. Pub. Health*, N. Y., 1917, **7**, 964.

45. Gordon, A. Knyvett: The clinical significance of laboratory tests for syphilis. *West London M. J.*, Lond., 1917, **22**, 62.

46. Kaplan: The four plus Wassermann. *N. York M. J.*, 1917, **105**, 728.

47. Knaut, E. V.: Wassermann reaction in 400 cases investigated by group study methods. *Journ. Am. Inj. Dis.*, St. Louis, 1917, **1**, 772.

48. Lereboullet et Rubinstein: Quelle valeur le praticien doit-il accorder, à la séro-réaction de la syphilis. *Bull. gén. de thér. méd. et chirurg.*, Par., 1917, **31**, 481, 500.

49. Oppenheim, R.: On the reliability of the Wassermann reaction; a study of the sources of error and an attempt to standardize the technic. *Journ. Am. Med. Ass.*, Chicago, 1917, **19**, 456.

50. Schmidt, I. E.: Clinical value of the blood Wassermann test. *Colorado M.*, Den., 1917, **39**, 185.

51. Freudenreich, A. "Zur Zuverlässigkeit der Wassermann'schen Reaktion bei Syphilis," *Münch. med. Wochenschr.*, 1917, **54**, 993.

52. Hecht, Julius. "Zur Frage der Zuverlässigkeit der Wassermann'schen Reaktion," *Münch. med. Wochenschr.*, 1917, **54**, 908.

53. Sobel, V. "Die experimentelle und die Wassermann-Reaktion bei der intravenösen Behandlung der Lues," *Klin. Therapie*, 1917, **79**, 65.

54. Stark, Caselman, and Bailey. "A year's work with the Wassermann test in the Boston Health Department laboratory with special reference to a modified technique," *Boston M. and S. J.*, 1917, **177**, 189.

55. Sonntag, Erich. "Die Wassermann'sche Reaktion unter Serologischen Technik- und Kasuistischen Bedingungen," Berlin, 1917, 194 S.

56. Wassermann. "Zur Frage der Zuverlässigkeit der Wassermann'schen Reaktion," *Berl. klin. Wochenschr.*, 1917, **54**, 105.

57. Wile, M. G. "A clinical consideration of the Wassermann reaction," *Medicine and surgery*, St. Louis, 1917, **1**, 368.

58. Mayer, Hermann. "Zur Frage der Divergenz der Wassermann'schen Reaktion," *Münch. med. Wochenschr.*, 1918, **55**, 86.

59. Freudenreich. "Zur Frage der Divergenz der Wassermann'schen Reaktion," *Münch. med. Wochenschr.*, 1918, **55**, 620.

II. REPORT ON THE WASSERMANN REACTIONS

Obtained by 104 *Cases by*

Carl H. Browning, M.D., Director of the Bland Sutton Institute of Pathology, Middlesex Hospital.

Colonel L. W. Harrison, D.S.O., K.H.P., Military Hospital, Rochester Row, London.

James McIntosh, M.D., Bacteriological Department, London Hospital.

Compiled by

J. H. Sequeira, M.D., F.R.C.P., F.R.C.S., Physician to the Skin Department, and Lecturer in Dermatology, London Hospital; in charge of Department for Syphilis, London Hospital; Hon. Consultant for Diseases of the Skin to the Military Hospitals in London, &c.

§ 1. *Object.*—The object of this inquiry is to compare the results of the Wassermann reactions performed by three well-known observers with a view to determining the relative value of their methods from the clinical standpoint.

§ 2. *Material.*—Between January 19 and April 10, 1918, 104 cases were used for this purpose. They were—

(a) 71 cases clinically syphilitic in all stages both treated and untreated, with the exception of young infants suffering from hereditary syphilis from whom it was deemed unwise to take so much blood as would be required for three separate examinations.

(b) 3 cases suspected to be syphilitic for diagnosis.

(*c*) 30 cases clinically non-syphilitic, including—

Ulcus molle.
Lupus vulgaris.
Lupus erythematosus.
Tuberculous ulcer.
Leprosy.
Scleroderma.
Scabies.
Psoriasis.
Seborrhoides.
Erythema.
Eczema marginatum (Tinea cruris).
Furunculosis.
Carbuncle.
Diabetes.
Graves' disease.
Follicular tonsillitis.
Acute rheumatism.
Ulcerative endocarditis.
Osteomyelitis.

The responsibility for the diagnosis (except in ten medical and surgical cases) is mine.

The blood was drawn in each case from a vein into tubes of the type provided by the Local Government Board. The tubes were corked and enclosed in the wooden boxes supplied and sent direct to the three laboratories, those to the Middlesex Hospital and Rochester Row being forwarded through the post, and those to the laboratory of the London Hospital being sent by hand. Each specimen was numbered, but *no clinical details were sent*. In some instances the specimens were broken or failed to arrive at the laboratories, and in other cases some doubt as to numbering occurred. Where possible second specimens were sent. This was not always practicable owing to the non-return of the patients to the clinic. In six specimens in all, therefore, there are no reports.

§ 3. *A possible source of error.*—It is important to note that fresh sheep's blood is necessary for the examination, and that immediately prior to the rationing of meat in the Metropolitan area there were weeks in which no sheep were killed, and that there has been some difficulty in obtaining fresh blood throughout the period during which the examinations were made. It is well known that formalinized blood introduces a possibility of error, and it would be advisable to inquire whether such blood was used in the laboratories while the investigations were proceeding.

[On inquiry the Committee find that formalinized corpuscles were used during several weeks by Dr. McIntosh.]

Tables 1 to 11 record the results of the Wassermann reactions with the clinical factors briefly stated. Table 12 gives an analysis of the results in the syphilitic cases. Table 13 gives a summary of these results. Table 14 gives a detailed comparison of the results returned by the three observers in three groups.

The reports of the three observers vary in their descriptions of the types of reaction.

1. Dr. Browning classifies his results in the sequence

+
+ Weak
Very weak
Suspicious
–

He was just enough to explain the significance of these descriptions (i.e. as positive, negative, etc.) in terms of treponemal tests for syphilis. It is a matter to which one would assent as a matter of law.

Weak positive

(a) Low titre of antibody, but one would not assent to it as positive in an unknown case.

(b) In a case of known syphilis who had previously reacted positive and who had been treated. His titre might be of value, but as positive it would indicate the need for further treatment.

Suspicious or doubtful

(a) Means a reaction which is not indicative, but which justifies the need for further investigation, e.g. if got in the clinic it would prompt the examination of the other children.

(b) In a known treated case it would, in some, have the same significance as 'weak positive'.

Negative. Of course, leaves the matter entirely to the judgement of the clinician.

2. Colonel Harrison very kindly wrote a synopsis for which he has kindly forwarded the following interpretation. He recognizes six degrees of reaction:—

Definite reactions are of three grades:

++ Six groups.
+ 5 the next.
+ ordinary positive.

Any weaker reaction would not be considered sufficient for a diagnosis.

Doubtful reactions are of two grades:

+ 4
+ 3

the latter being practically negative.

If the case is a treated one these reactions are considered indicative for further treatment.

If the case has not yet been diagnosed the usual procedure after receiving a + or + 4 report is to give a preventive injection of '606' or '914' and not further enquire, but the reaction must be interpreted + 4 as usual before a diagnosis is finally made.

Negative reactions are indicated by the sign –

3. Dr. McIntosh returns his results in the sequence. He writes to explain as regards:

The results given are taken from the diagnostic report as I understand the Medical Officer has used the wording of the question, the first and fourth rather than quantitative. Four degrees of reaction are recorded:

1. Positive, probably cases of hereditary.
2. Positive, presumably recent positives.
3. Negative (cases which it is doubtful would form the diagnostic view, but I believe it is better to err on the safe side and especially to treat cases).
4. Negative.

TABLE I. SYPHILIS. PRIMARY. UNTREATED. 15 CASES.

[illegible] No.	Sex	Age	Site	Supposed duration	Dr. [illegible]	Ch. Harrison	Dr. W. J. [illegible]
7	M	53	penis	18 days	+	+	test unsatisfactory
10	M	30	penis	1 week	suspicious	–	negative [illegible]
16	F	21	lower lip	2 weeks	very suspicious	–	–
20	M	42	penis phagedenic	14 days	+	+ +	-
29	M	27	penis	3 weeks	–	–	–
36	M	20	penis	3 weeks	+	- -	+
42	F	22	labium	1 month	+	+ +	-
44	M	38	penis	3 weeks	-	+ +	- incomplete
49	F	22	vulva	14 days	+	+ +	+
60	M	21	penis	10 days	-	+ +	+
65	F	22	vulva	5 weeks	+	- -	+
66	M	22	penis	1 week	–	- -	+
72	M	27	penis	1 month	+	- -	-
73	M	21	penis	3 weeks	-	- -	+
78	M	24	penis	1 month	-	- -	-

TABLE II. SYPHILIS. PRIMARY. TREATED. 4 CASES.

[illegible] No.	Sex	Age	Site	Date	W. R. [illegible] 'positive'	Treatment	Dr. [illegible]	Ch. Harrison	Dr. W. J. [illegible]
27	M	31	penis Spiro-chaetes	March 30, 1916	+	Galyl 0·3, 0·4, 0·4 Hg. 8 intra-muscular	–	–	–
41	F	?	labium	1916	-	Galyl 0·3, 0·3, 0·4 Hg. 8 intra muscular, last June, 1917	–		
59	M	26	penis	March 4, 1917	-	N A B 0·6, 0·9, 0·9 Hg. 8 intra-muscular last May, 1917	–		
67	F	20	labium	July, 1917	-	N A B 0·6 0·6 0·9 Hg. 8 intra-muscular last Sept. 1917	–	–	–

N.A.B. = Novarsen billon.

TABLE III. SYPHILIS GENERALIZED (SECONDARY) UNTREATED. 20 CASES.

Case No.	Sex	Age	Time and character of primary	Skin	Throat	Glands	Other symptoms	Int. (Months)	Cal. (months)	Int. Mercurials
1	M	26	papule 2 weeks	polymorphic rash	ulcers	+	primary still present	1	2–3	+
2	F	32	labium "chancre"	papular	nil	+	primary still present	1	2–3	+
3	F	27	[illegible]	condylomata	ulcers	+	ulcerative syphilitic	1	2–3	+
4	M	29	[illegible] 3 years	papulo-squamous	mucous patches	+		1	2–3	+
5	M	29	papule 3 months	nil	mucous patches, &c.	+		1	2–3	+
6	M	31	[illegible] 6 weeks	profuse papulo-squamous	mucous patches	+	headache, [illegible] treatment	1	2–3	+
7	M	28	papule 6 months	profuse papulo-squamous	mucous patches	+			2–3	+
8	M	29	papule 3 months	rash Dec. 2	mucous patches	+	headache, [illegible]	1 week	2–3	+
9	F	24	[illegible]	papular, tubercular	small track ulcers	+	headache	[illegible]	2–3	+
10	F	26	[illegible]	papulo-squamous	nil	+		1	2–3	+

15	F	35	no history	profuse + papal	mucous patches	+	9 months pregnant	specimen not received	+ +	+	
16	M		gonorrhœa July, 1917 no sore seen	papular Nov. 17	nil	+		+ weak	+ +	+	
68	F	25	vulva 15 weeks	rash 5 days	mucous patches lips	+		+	+ +	+	
89	F	23	no history	papulo-squamous Dec. 1	nil	+		+	+ +	+	
74	F	20	no history	general papular	ulcers	+	had had one dose hanged 0·15	+	+ +	+	
59	M	44	penis June, 1917	Syphilitic rash	Syphilitic ulcers	+	N.A.B. 0·6 one week before	+	+ +	+	
88	F	20	no history	general + condylomata	ulcers	+		+	+ +	+	
28	M	23	penis 9 months	papular general	mucous patches mouth	+	hair falling +	+	+ +	+	
89	M	38	none seen, discharge 1 year	nil	painful tongue mucous patches	+	'perfect' tongue	+	+ +	+	
94 A	F	26	labium 6 weeks	nil	snail track ulcers	+		+	+ +	+	

TABLE IV. SYPHILIS, GENERALIZED (SECONDARY) TREATED 11 CASES

Number	Sex	Age	Duration before admission	Lesions	Glands	Cervix	W. R. before treatment	Treatment	Result	Later history	No. of pregnancies
2	M	27	patchy 4 years	[illegible]	—	+	+ Dec. [illegible] 1913	[illegible] 1913 [illegible] 0.3, 0.4, 0.5 and 6 Hg	—	[illegible]	[illegible]
3	M	[illegible]	patchy 3 years	[illegible]	—	+	+ June 28, 1913	1913 Tepid [illegible] 0.6 and 7 Hg at Local Hospital	[illegible]	[illegible]	[illegible]
[illegible]	M	28	[illegible] 1913 patchy	[illegible]	+	+	+ August, 1913	1913 Aug. Sept. N.A.B. 0.6, 0.9, 0.9 and 8 Hg 1913 Aug. Sept. [illegible] 0.3, 0.4, 0.4 and 8 Hg	+ [illegible]	[illegible]	[illegible]
26	M	31	patchy May, 1913	papular	—	+	+	1913 N.A.B. 0.6 0.9 0.9 and 8 Hg last Sept	—	[illegible]	[illegible]
31	M	23	patchy Oct. 1913	[illegible]	—	+	+ October, 1916	1916 July, [illegible] 0.4, 0.4, 0.4 and 7 Hg 1917 Jan. March 8 Hg 1917 July Aug. [illegible] 0.4, 0.4, 0.4 and 8 Hg +	—	—	—
32	F	23	[illegible]	[illegible]	—	+	+ [illegible] 1913	1917 April [illegible] 0.4, 0.4, 0.4 N.A.B. 0.6 12 Hg	[illegible]	+	[illegible]
42	F	31	[illegible]	[illegible]	+	+	+ [illegible] 1913	1913 Oct. Dec. 0.2, 0.3, 0.4 8 Hg	[illegible]	—	—
58	F	23	patchy Nov. 1913	macular	nil	+	+ Oct. 23, 1913	1913 Oct. Dec. 0.3, 0.4, 0.5 8 Hg	—	—	—
104	M	23	patchy Oct. 17	papular	+	+	+	1913 Dec. 1913 Jan. 0.3, 0.4, 0.4, 0.4 8 Hg	—	+	—
[illegible]	F	23	[illegible]	papular [illegible]	+	+	+ [illegible] 1913	1913 Dec. 1914 Jan. 0.3, 0.4, 0.4, 0.4 8 Hg	—	—	—
45	M	[illegible]	[illegible] years	all general	—	—	+	[illegible] [illegible] [illegible] [illegible] [illegible]	—	—	—

TABLE V. SYPHILIS, LATE (TERTIARY) UNTREATED. 7 CASES.

Research No.	Sex	Age	Date primary	Nature of Lesions	Dr. Browning	Col. Harrison	Dr. M. [illegible]
4	F	32	?	Gummatous ulcer of leg, verified by microscope Dr. Turnbull ; old pelvic cellulitis.	-	+ +	+
35	M	34	?	Gumma of palate, nasal septum destroyed, soft palate partially destroyed.	+	+ +	+
37	M	45	?	Gumma of testis.	+	+ +	+
53	F	39	?	Gumma of ankle. 7 children, 2 pairs of twins, no miscarriage.	+	+ +	+ trace of haemolysis
68	F	39	?	Gummatous ulcer of knee. 13 children, 7 alive, 2 miscarriages, 1 still birth.	+	+ +	+
83	M	30	?	Extensive ulceration of fauces with much loss of tissue. Also had diphtheria—Klebs Loeffler B. found	+	+ +	+
92	F	30	?	Gummatous ulcer of right leg 9 weeks. Impetigo-like eruption of scalp 3 months.	+	+ +	+

TABLE VI. SYPHILIS, LATE NERVOUS.

Research No.	Sex	Age	Date primary	Nature of Lesions	Dr. Browning	Col. Harrison	Dr. M. [illegible]
80	M	45	?	Left hemiplegia 4 weeks before. K. J. + + Spastic gait. Scars of gummata on legs. No regular treatment.	-	+ +	+

TABLE VII. SYPHILIS, LATE (TERTIARY) TREATED: 7 CASES.

Case No.	Sex	Age	Duration of disease	Lesions	B. W. Reaction	Treatment	Wt. 1st attendance	Wt. 2nd attendance	Wt. Months
6	M	30	[illegible] years	[illegible]	+	N A B 0·6 0·9 0·9 0·9 Hg [illegible]		[illegible]	[illegible]
7	F	29	1	Old tubero-ulcerative lesions of palate, larynx, pharynx, and [illegible]	+	Mercury rubbed in intramuscularly. No iodide	—	[illegible]	—
10	F	28	7	Large healed ulcerative lesion upon outer surface of [illegible]	+	[illegible] Hg [illegible] K I [illegible]	—	—	— incomplete
21	F	22	3	Gummata of face.	+	[illegible]	—	[illegible]	[illegible] much damaged
58	M	40	[illegible] 13 years	Gummatous ulcer of [illegible]	+ Aug. 1920	[illegible] Hg and K I alternately to Dec. 1917	suspicious	[illegible]	—
76	M	40	3	Advanced [illegible]	+	[illegible] N A B 0·6, 0·9, 0·9, 0·9 Hg	—	[illegible]	—
91	F	35	3	Gummatous [illegible]	Months [illegible] + Dec. 9 1918 +	March April 1917 N A B 0·6 0·9 0·9 Hg Hg and K I [illegible] to Sept. 1918	—	—	—

Table VIII. Syphilis: Latent. 3 Cases.

Hospital No.	Sex	Age	Symptoms	Sc. Reaction	Col. Reaction	Ag. Method
5	F	32	Mother of a congenital syphilitic infant. Herself had a rash on buttocks, legs and neck. Specific. Has a healthy child born after two miscarriages since.	-	+ +	+
62	M	34	Sent by surgeon who was treating him for ulcer, because there was a history of a rash six years before. Glands +. Condylomata. Throat unaffected.	- weak	-	+
75	M	50	Wife and child W. R. - Patient has no symptoms and gives no history pointing to syphilis.	-	- -	+

Table IX. Syphilis, Hereditary (Congenital). 3 Cases.

Hospital No.	Sex	Age	Symptoms	Sc. Reaction	Col. Reaction	Ag. Method
56	F	14	Complete deafness. Hutchinson's teeth. Interstitial keratitis. Perforation of nasal septum ozæna. W. R. + previously. Mc Intosh.	-	- -	Specimen damaged
81	F	9	Hutchinson's teeth. Perforation of hard palate. Depressed nose. Ulceration of nasal cavities, ozæna.	-	- -	+
93	F	13	Old interstitial keratitis. Deaf. Teeth [illegible]	-	+	-

Table X. Cases sent for Diagnosis. 3 Cases.

Serial No.	Sex	Age	Particulars of case	Mr. Browning	Dr. Hutchinson	Mr. Bracknell
27	M	65	Seven months ago [illegible] on the body. One [illegible] Could [illegible] not be certain as to syphilis.	Probably syphilitic	–	–
28	F	31	Her married sister with whom she was staying, landed at London Hospital for secondary syphilis, mucous patches, &c. The patient had seen a rash on her face [illegible] days before. W. R. + ++. Dr. McDonnell, at London, gave [illegible] treatment.	–	±	– Probably syphilitic
48	M	35	Vaccination. Husband of No. 43, who had a pustular secondary rash. This must be said to have had a "cold" some fifteen months before. W. R. +. He went back to France, but his affected lip healed with Ammoniated Hg ointment. Now [illegible] III, p. 14.	–	–	–

In No. 44, the [illegible] syphilitic history was suppressed on diagnosis [illegible] of [illegible] &c. They are recorded in Table VI.

Table XI. Non-Syphilitic Cases. Classified. 25 Cases.

Research No.	Sex	Age	Nature of Case	Dr. Bronson	Col. Harrison	Dr. McIntosh
13	M	20	Ulcus molle, foreskin 3 weeks appearing 7 days after coitus, glands not indurated, no treatment.	–	–	–
2	M	28	Lupus vulgaris exulcerans 4 years. Nose affected.	+	–	–
46	M	22	Lupus vulgaris 4 years. Operation for tuberculous glands at West London Hospital. Chest, face, neck, and shoulders affected.	–	–	–
61	M	21	Lupus vulgaris since early childhood. Nose affected + + ulceration.	–	–	–
90	F	3?	Lupus vulgaris, 10 years extensive ulceration of nose with destruction of cartilaginous septum.	not examined	–	–
98	M	15	Lupus vulgaris 11 years. Both sides of face affected. Nose ulcerated. Glands of neck +.	–	–	–
43	M	32	**Tuberculous ulcer of lower lip.** Gland +. Advanced pulmonary tuberculosis (Dr. Cecil Wall), direct infection of lip by sputum. So called 'Tuberculosis cutis orificialis'.	–	–	–
32	F	31	Lupus erythematosus, acute outbreak in chronic case. Rigors. T 104·2. Blood taken next day. Eruption face and hands.	–	–	–
55	F	40	Lupus erythematosus. Old tuberculous glands of neck. Breast removed for tuberculosis, May 1917. Eruption on cheeks, ears, &c. Alopecia.	–	–	–
3–	F	4–	Lupus erythematosus in a deaf mute. Chronic type 9 years' duration.	–	–	–
5?	M	30	Leprosy, contracted in the East. Maculo-anæsthetic type, 10 years. Ulnar thickening, atrophy of interossei. Hansen's bacilli found. No history or sign of syphilis.	–	+ [illegible] at least	–
64	F	5–	Leprosy, contracted in Odessa, at least 12 years' duration. Nodular type. Hansen's bacilli demonstrated in sections.	–	–	–

* [illegible] p. 11

TABLE XI. NON-SYPHILITIC CASES, CLASSIFIED AS TO [illegible]

[illegible] No.	Sex	Age	[illegible] Diagnosis	Dr [illegible]	[illegible] Blood	[illegible] Fluid
18	F	18	Secondary anæmia. Many spots. Acute type, with some fever. Severe. No history of syphilis.	—	— no reaction to 40 [illegible]	— [illegible]
21	M	20	Severe [illegible] pneumonia [illegible]	—	[illegible]	—
27	M	28	Severe [illegible] with [illegible] symptoms of syphilis, quite unlike [illegible] and no history of chancre. No treatment. Syphilis [illegible] was negative to [illegible]	—	[illegible]	—
29	M	3	[illegible] — [illegible]	—	—	[illegible]
31	F	39	Severe [illegible] [illegible] and [illegible] affected. Dying.	—	—	—
39	M	22	Severe [illegible], chest [illegible] and back affected. Dying.	—	—	—
40	F	32	Lupus, causing [illegible] [illegible] and [illegible] of the [illegible] and [illegible] [illegible]	—	[illegible]	—
70	F	26	Erythema of the palms with swollen joints [illegible] rheumatoid arthritis. Child died at birth. W. R. taken as an example to this	—	—	—
83	I	10	Furunculosis and carbuncle. No organ. History of [illegible] organs and [illegible] [illegible] infancy and [illegible]	[illegible]	—	—
92	M	36	Carcinoma. Ill one week. No organ. Had had one dose of [illegible] a [illegible] [illegible] was taken.	[illegible]	— no reaction to [illegible]	—
97	M	12	Diabetes. Grossly wasted child passing a large [illegible] of sugar.	—	—	—
101	M	13	Diabetes mellitus. Diabetes at least 2 years. An [illegible] of sugar 1.[illegible]	[illegible]	—	—
103	I	5	Cerebral [illegible]. Typical [illegible] [illegible] [illegible] [illegible] [illegible] [illegible]	—	—	—

Table XI. Non-Syphilitic Cases. Classified (*cont.*).

Reference No.	Sex	Age	Nature of Case	Dr. [illegible]	Col. Harrison	Dr. [illegible]
38	M	21	Follicular tonsillitis. Strepto-coccal (Dr. Panton).	—		-
95 A	F	14	Acute rheumatism. T. 101°. F. Heart free, elbows and knees affected. Profuse sweating.	—	—	—
96	M	?	Ulcerative endocarditis. T 103° to 104°. Mitral systolic murmur. Septic appearance. The blood clotted at once on removal	—	—	—
100	M	16	Osteomyelitis of femur, 3 months' duration. Septic temperature.	-	-	—
102	M	11	Osteomyelitis of femur, 3 months' duration. Septic temperature.	— suspicious	±	—

(*a*) Leprosy sometimes gives a positive reaction. In my experience of 14 cases, the reaction was always negative in macilo-anaesthetic cases and it is generally recognized as being commoner in the nodular variety.

(*b*) Scleroderma has been reported by other observers as giving a positive reaction. In four of my cases it was negative.

This patient had had an injection of vaccine six hours before blood was taken. I do not think this is of moment, but put it on record. The Committee call attention to the fact that in this case a positive result was obtained in Dr. Browning's laboratory, at Rochester Row, and by Dr. Donald: see Table XIV., who tested the same sample of serum as did Dr. McIntosh. Col. Harrison informs the Committee that the reaction obtained in his laboratory was confirmed in the second tube. A further sample of this blood, obtained by Dr. McIntosh at a later date, on being tested gave a positive reaction in his hands also. On serological evidence it would appear therefore that this case was one of latent syphilis.

TABLE XII. ANALYSIS OF RESULTS IN SYPHILITIC CASES.

A. UNTREATED CASES.

Primary, 15 cases:			
Positive	11	11	11
Suspicious	2	2	2
Negative	2	2	2
Not tested	0	0	0
	15	15	15
Secondary, 20 cases:			
Positive	17 (1 week)	20	20
Suspicious	0	0	0
Negative	3	0	0
Not tested	3	0	0
	23	20	20
Tertiary and Late Syphilis, 8 cases:			
Positive	7	8	8
Suspicious	0	0	0
Negative	1	0	0
Not tested	0	0	0
	8	8	8
Latent, 3 cases:			
Positive	3 (1 week)	3	3
Suspicious	0	0	0
Negative	0	0	0
Not tested	0	0	0
	3	3	3
Hereditary, 3 cases:			
Positive	3	3	3
Suspicious	0	0	0
Negative	0	0	0
Not tested	0	0	0
	3	3	3

B. TREATED CASES.

Primary, 4 cases. W. R. before treatment:			
Positive	4	4	4
Suspicious	0	0	0
Negative	1	1	1
Not tested	0	0	0
	4	4	4
Secondary, 11 cases:			
Positive	5 (1 week)	5	5
Suspicious	0	0	0
Negative	6	6	6
Not tested	0	0	0
	11	11	11
Tertiary, 7 cases:			
Positive	0	0	1 (Cerebrospinal)
Suspicious	1	2	0
Negative	4	4	4
Not tested	0	0	2
	5	6	7

Table XIII. Summary of Results.

A. Untreated cases of syphilis — 49

	Dr. Browning	*Col. Harrison*	*Dr. McIntosh*
Positive	41 (3 weak)	45	44 (1 incomplete)
Suspicious	2	1	1
Negative	5	3	2
No return	1	0	2
	49	49	49

B. Treated cases of syphilis — 22

	Dr. Browning	*Col. Harrison*	*Dr. McIntosh*
Positive	5 (1 weak)	8	9 (1 incomplete)
Suspicious	4	4	0
Negative	13	10	12
No return	0	0	1
	22	22	22

C. Cases sent for 'diagnosis' — 3

	Dr. Browning	*Col. Harrison*	*Dr. McIntosh*
Positive	0	0	0
Suspicious	0	1	0
Negative	2	2	3
No return	1	0	0
	3	3	3

D. Cases with no clinical evidence of syphilis — 30

	Dr. Browning	*Col. Harrison*	*Dr. McIntosh*
Positive	2	2	0
Suspicious	1	2	1 (trace)
Negative	26	26	29
No return	1	0	0
	30	30	30

The detailed comparison of the results returned by the three observers is instructive. To make this perfectly fair I have excluded those cases in which one or other observer failed to make returns. These failures were due to non-receipt or breakage of specimens, or some doubt as to proper numbering.

(a) *Comparison of Dr. Browning's with Colonel Harrison's results.*

101 cases were compared.
In 84 cases the results were identical.
In 10 cases the differences on the returns were important:

Syphilitic cases	*Browning*	*Harrison*	*Diagnoses*
No. 7	+	±	Primary
66	–	+	Primary untreated
12	–	+	Secondary treated
17	–	+	Tertiary treated
19	–	+	Secondary untreated
23	–	+	Secondary untreated
25	– suspicious	+	Secondary treated
80	–	+	Tertiary untreated
Non-syphilitic cases			
2	+	–	Lupus
71	–	+	Scleroderma

Minor differences were as follows:

Case	[illegible]	[illegible]	
" 8	[illegible]	-	Tertiary treated
" 10	[illegible]	—	Primary untreated
" 14	very suspicious	—	Primary untreated
" 28	—	+	Tertiary treated
" 52	[illegible]	—	Secondary treated
" 94	—	+	Secondary treated
" 97	—	+	Leprosy

(d) Comparison of Dr. Bi[illegible]'s with Dr. M. Listed's results.

98 cases were compared, no returns having been made from each of these gentlemen in three cases.

81 results were identical.

In 11 cases the difference in the returns was important:

[illegible]	[illegible]	M[illegible]	
8		-	Tertiary treated
12	—	-	Secondary treated
17	—	-	Tertiary treated
18	[illegible]	[illegible]	Tertiary treated
19	—	-	Secondary suspected
23	—	-	Syphilis suspected
25	[illegible]	-	Syphilis treated
66	—	-	Primary untreated
80	—	-	Tertiary untreated
[illegible]			
2	+	—	Lupus
99	+	-	Carbuncles

Minor variations were as follows:

16	very suspicious		Primary untreated
54	suspicious	—	Secondary treated
52	suspicious	-	Secondary treated
58	suspicious	-	Tertiary treated
71	—	[illegible]	Non-syphilitic
102	[illegible] suspicious	—	Non-syphilitic

(e) Comparison of Colonel Harrison's with Dr. McListed's results.

101 cases were compared.

90 results were identical.

In no syphilitic cases were the differences serious, the only marked variation was in the following non-syphilitic case:

Case	99	[illegible]	[illegible]	Carbuncles

Minor variations were as follows:

Case	8	+	+	Tertiary treated
"	18	—	[illegible]	Tertiary treated
"	54	+	[illegible]	Treated case
"	58	+	[illegible]	Tertiary treated
"	91	+	—	Secondary treated
"	71	+	[illegible]	Scleroderma
"	102	+	—	Osteomyelitis
"	13	—	[illegible]	Tertiary untreated
"	28	+	[illegible]	Secondary treated for [illegible]
"	57	+	[illegible]	Leprosy

§ 5. *Conclusions.*

(1) The techniques of Colonel Harrison and Dr. McIntosh give remarkably close results, the only important divergence being in a case of carbuncles (clinically non-syphilitic) which Colonel Harrison returned as + ± and Dr. McIntosh as negative. Dr. Browning returned the same case as +.

In three syphilitic cases (all treated) Dr. McIntosh's technique appeared more sensitive than that of Colonel Harrison:

	Harrison.	*McIntosh.*	
Case 8	-	+	Tertiary treated
,, 18	—	+ incomplete	Tertiary treated
,, 10	—	trace	Primary untreated

while in three other syphilitic cases (all treated) Colonel Harrison's reaction suggests a greater sensibility than that of Dr. McIntosh:

Case 51	±	—	
,, 58	±	—	
,, 94	±	—	

Colonel Harrison's results also showed a + reaction in (71) a case of scleroderma (McIntosh — trace, Browning —), and a ± in (102) a case of osteomyelitis with fever (McIntosh — (suspicious), Browning —).

(2) Dr. Browning's results compared with the other two observers are not so close and differ from the clinical diagnosis in several instances:

	Browning.	*Harrison.*	*McIntosh.*
Primary untreated syphilis			
No. 7	-	-	No return
* ,, 66	—	-	-
Secondary untreated syphilis			
* No. 19	—	-	-
,, 22	trace	-	-
* ,, 23	—	-	-
Secondary treated syphilis			
* No. 12	—	-	
* ,, 14	trace	-	-
* ,, 25	— suspicious	-	-
Tertiary treated syphilis			
* No. 17	—	-	
Lupus vulgaris			
* No. 2	-	—	

Those marked with * are important clinically, and five of the eight occurred in one batch of specimens the blood being taken on February 7, 1918.* The other differences were negligible. Nos. 10 and 16 (primary untreated) were returned 'suspicious' and 'very suspicious' when Colonel Harrison gave negative reports, and Dr. McIntosh returned them respectively as 'negative trace' and 'positive incomplete'.

(3) It would be an advantage if a standardized technique be introduced, to insist on a standard system of returns which for the purposes of the general practitioner should, I think, be as simple as possible and in a qualitative rather than a quantitative sense. The practitioner wants to know (a) if untreated whether his patient is syphilitic or not, i. e. whether anti-syphilitic treatment is or is not required, (b) in a treated case, whether he is to continue treatment. Quantitative reports would, of course, be of value in the venereal clinics especially for the comparison of the methods of treatment.

Dr. Browning desires it to be known that Dr. E. L. Kennaway was associated with him in the observations recorded in this research.

I should like to acknowledge my indebtedness to my clinical assistant, Dr. Vilvandré, who has given me valuable help in taking the specimens of blood and in the notes of the cases and to my colleagues at the London Hospital for placing at my disposal ten medical and surgical cases.

* The Committee think it fair to Dr. Browning to state their opinion that the value of his method should not be judged by these five divergent results. It is probable that some defect existed in his technique on one particular day, for the sera from the same cases were subsequently tested in the Laboratory with results substantially concurring with those reached by the other observers.

Further, in the case of one apparently erroneous result sent in by Dr. Browning, viz. No. 2, Case number, the laboratory records were found to show that the correct result was negative, and not positive as appears in Dr. Stephens' Table XI and Dr. Browning's summaries. The Committee have satisfied themselves that in this instance the wrong return was due to a simple clerical error on Dr. Browning's part. They would draw attention to this example of the readiness with which clerical errors may contribute to the apparent inaccuracies of the test.

III

TABULAR SUMMARY OF THE RESULTS

Table XIV. TABULAR SUMMARY OF THE RESULTS.

Patient No.	Sex	Age	Clinical Features	(a) Recovery	(b) Luetin	(c) Wassermann	(d) Control and p. f.
1	M	26	Secondary syphilis: untreated	—	+ +	+	+
2	M	28	Lupus vulgaris	+	—	—	—
3	F	22	Secondary syphilis: untreated	—	+ +	+	+
4	F	32	Tertiary syphilis: untreated	—	+ +	+	+
5	F	[illegible]	Latent syphilis	—	+ +	+	+
6	F	47	Secondary syphilis: untreated	—	+ +	+	+
7	M	33	Primary syphilis, penis. 18 days	+	—	test unsatisfactory	test and control had each about 20 haemolytic units
8	M	30	Tertiary syphilis: treated	—	+	+	poor, incomplete
9	M	29	Secondary syphilis: untreated	—	+ +	+	not tested
10	M	30	Primary syphilis, penis. 1 week	suspicious	—	neg. trace	partially +
11	M	29	Secondary syphilis: untreated	—	+ +	+	+
12	M	28	Secondary syphilis: treated	—	+ +	+	—
13	M	20	Ulcus molle	—	—	—	—
14	M	28	Secondary syphilis: treated	+ (weak)	+ +	+	+
15	M	21	Secondary syphilis: untreated	+	+ +	+	+
16	F	21	Primary syphilis, lower lip. 2 weeks	very suspicious	—	—	neg. incomplete
17	F	36	Tertiary syphilis: treated	—	+ +	+	—
18	F	36	Tertiary syphilis: treated	—	—	+ incomplete	+ incomplete
19	M	30	Secondary syphilis: untreated	+	+ +	+	+
20	M	32	Primary syphilis, penis: untreated	+	+ +	+	+
21	M	26	Stricture	—	—	—	—
22	M	29	Secondary syphilis: untreated	+ (weak)	+ +	+	+
23	F	23	Secondary syphilis: untreated	+	+ +	+	+
24	M	8	Psoriasis	—	—	—	—
25	M	28	Secondary syphilis: treated	suspicious	+ +	+	+

26	M	34	Secondary syphilis: treated	+	+ +	+	+	
27	M	05	Sores on body 7 months ago. Syph.?	not examined	—	—	—	
28	F	31	Sores on feet	—	+	—	—	
29	M	29	Primary syphilis, penis: untreated	+	+	+	+	
30	F	50	Secondary syphilis: untreated	+	+ +	+	+	
31	F	39	Seborrhoeide: not syphilitic	—	—	—	—	
32	F	32	Lupus erythematosus	—	—	—	—	
33	M	31	Primary syphilis: treated	—	—	—	—	
34	M	13	Secondary syphilis: treated	—	—	—	—	
35	M	34	Tertiary syphilis: untreated	+	+ +	+	+	
36	M	20	Primary syphilis, penis: untreated	+	+ +	+	+	
37	M	45	Tertiary syphilis: untreated	+	+ +	+	+	
38	M	21	Follicular tonsillitis	—	—	—	—	
39	M	22	Seborrhoeide—not syphilitic	—	—	—	—	
40	F	82	Eczema marginatum	—	—	—	—	
41	F	?	Primary syphilis: treated	—	—	—	—	
42	F	22	Primary syphilis, labium: untreated	+	+ +	+	+	
43	M	42	Tuberculous ulcer of lip: phthisis	—	—	—	—	
44	M	38	Primary syphilis, penis: untreated	+	+ +	+ (incomplete)	+ — incomplete	
45	M	37	Secondary syphilis: treated	—	—	—	—	
46	M	22	Lupus vulgaris	—	—	—	—	
47	I	23	Secondary syphilis: untreated	not examined	+ +	+	+	
48	M	45	Husband of No. 47. 'Soft sore' 3 months ago	—	—	—	—	
49	F	22	Primary syphilis, vulva: untreated	+	+ +	+	+	
50	M	?	Secondary syphilis: untreated	+ weak	+ +	+	+	
51	F	27	Secondary syphilis: treated	suspicious	+	+	—	
52	F	26	Secondary syphilis: treated	suspicious	—	—	—	
53	F	39	Tertiary syphilis: untreated	+	+ +	+ tr. of haemol.	+	
54	F	22	Tertiary syphilis: treated	+	+ +	not examined	not examined	
55	F	40	Lupus erythematosus	—	—	—	—	
56	F	14	Congenital syphilis	+	+ +	not examined	not examined	
57	M	50	Lepra maculo-anaesthetica	—	—	—	—	
58	M	40	Tertiary syphilis: treated	suspicious	—	—	—	

TABLE XIV. TABULAR SUMMARY OF THE RESULTS (*continued*).

Case No.	Sex	Age	Clinical diagnosis	Dr. Browning	Dr. Harris	Dr. McIntosh	Dr. Donald
59	M	26	Primary syphilis: treated	—	—	—	—
60	M	21	Primary syphilis: untreated	+	+ +	+	+
61	M	21	Lupus vulgaris	—	—	—	—
62	M	41	History of rash 1 year ago. Glands +	+ (weak	+ +	+	+
63	F	40	Furunculosis and carbuncle	—	—	—	—
64	F	58	Lupus tuberosus	—	—	—	—
65	F	22	Primary syphilis: untreated	+	+ +	+	+
66	M	22	Primary syphilis: untreated	—	+ +	+	not examined
67	F	28	Secondary syphilis: untreated	+	+ +	+	+
68	F	39	Tertiary syphilis: untreated	+	+ +	+	+
69	F	23	Secondary syphilis: untreated	+	+ +	+	+
70	F	26	Erythema et palmæ	—	—	—	—
71	F	18	Sclerodermia—morphœa	—	+	Trace	—
72	M	23	Primary syphilis: untreated	+	+ +	+	+
73	M	20	Primary syphilis: untreated	+	+ +	+	+
74	F	20	Secondary syphilis: untreated	+	+ +	+	+
75	M	50	Latent syphilis. Wife and child W. R. +	+	+ +	+	+
76	M	40	Tertiary syphilis: treated	+	+ +	+	+
77	M	26	Scabies, sore throat	—	—	—	—
78	M	23	Primary syphilis: untreated	+	+ +	+	+
79	M	44	Secondary syphilis: untreated	+	+ +	+	+
80	M	43	Tertiary syphilis: untreated	—	+ +	+	+
81	F	9	Congenital syphilis	+	+ +	+	+
82	F	52	Lupus erythematosus	—	—	—	—
83	M	30	Tertiary syphilis: untreated	+	+ +	+	+
84	F	20	Secondary syphilis: untreated	+	+ +	+	+
85	F	35	Graves' disease	—	—	—	—
86	F	14	Secondary syphilis: treated	—	—	—	—
87	F	20	Primary syphilis: treated	—	—	—	—
88	M	23	Secondary syphilis: untreated	+	+ +	+	+
89	M	35	Secondary syphilis: untreated	+	+ +	+	+

90	F	41	Lupus vulgaris	not examined	—	—	—
91	F	35	Tertiary syphilis: treated	—	—	—	—
92	F	30	Tertiary syphilis: untreated	+	+	+	+
93	F	13	Congenital syphilis	+	+	+	+
94	M	23	Secondary syphilis: treated	—	±	—	—
94 A	F	26	Secondary syphilis: untreated	+	+	+	+
95 A	F	14	Acute rheumatism	—	—	—	—
97	M	?	Ulcerative endocarditis	—	—	—	—
97	M	12	Diabetes	—	—	—	—
98	M	15	Lupus vulgaris	—	—	—	—
*99	M	30	Carbuncles	+	+	+	+
100	M	16	Osteomyelitis of femur	—	—	—	—
101	M	53	Diabetic gangrene	—	—	—	—
102	M	11	Osteomyelitis of femur	—	±	—	—
103	F	23	Secondary syphilis: treated	suspicious +	+	+	+

* See note c, p. 43.

IV. CONCLUSIONS OF THE COMMITTEE

The Committee have thought it right in presenting Dr. Sequeira's report, to publish the original returns sent in by each observer as they stood. Where errors were subsequently discovered, they have been indicated in foot-notes and it is noteworthy that if account be taken of these the evidence as to the accuracy of the test itself is strengthened. In other words, Dr. Sequeira's summaries exaggerate the margin of mistakes actually committed in the testing.

Upon the study of all the observations presented in this Report, the Committee consider that in the hands of those whose previous record entitles them to be considered as experts, the percentage of positive Wassermann reactions in active syphilis is so high that the test may, for all practical purposes, be looked upon as specific. It must not be forgotten that the performance of the Wassermann test involves one of the most complicated methods that have been applied to diagnosis in medicine, a fact which has already been emphasized by the Committee in their former report upon its technique. Practised as it has been by all sorts of laboratory workers, it was only to be anticipated that in some instances at least inaccurate or fallacious results should have been obtained. Such failures have in certain quarters led to a scepticism with regard to the results, or even to the value of the method itself. Much of the criticism and scepticism, however, has been based on mere statement, and a searching inquiry into the literature of the last eight years reveals, in the opinion of the Committee, really very little that can be classed as proved inaccuracy. There is, indeed, a much greater volume of published evidence in favour of the Wassermann test.

It cannot be expected that this, or indeed any similar biological test, should invariably reveal the presence of some particular disease. The diagnostic value of any such test may be impaired either by the imperfection of the test itself, or by some failure in its performance, or by idiosyncrasy of the patient, whereby he may fail to react characteristically.

The Committee had these points in mind when they undertook the fresh investigation which has been given above. While the number of cases in this is small compared with that in some of the published series referred to, the Committee can claim that the work has been done as carefully and as objectively as possible by all concerned, and it is now recorded with a wealth of detail which has not been provided in any similar publication. From the records given here it is believed that any intelligent reader will be able to form his own opinion of the clinical value of the Wassermann reaction.

NATIONAL HEALTH INSURANCE

MEDICAL RESEARCH COMMITTEE

An Inquiry into the Prevalence and Aetiology of Tuberculosis among Industrial Workers, with special reference to Female Munition Workers

LONDON
PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE.
To be purchased through any Bookseller or directly from
H.M. STATIONERY OFFICE at the following addresses:
Imperial House, Kingsway, London, W.C. 2, and
28 Abingdon Street, London, S.W. 1;
37 Peter Street, Manchester;
1 St. Andrew's Crescent, Cardiff;
23 Forth Street, Edinburgh;
or from E. PONSONBY, Ltd., 116 Grafton Street, Dublin.

1919

Price 1s 6d. net

MEDICAL RESEARCH COMMITTEE

The following publications relating to the work of the Medical Research Committee can be purchased through any bookseller, or directly from H.M. Stationery Office, at the following addresses: Imperial House, Kingsway, London, W.C. 2, and 28 Abingdon Street, London, S.W. 1; 37 Peter Street, Manchester; 1 St. Andrew's Crescent, Cardiff; 23 Forth Street, Edinburgh; or from E. Ponsonby, Ltd., 116 Grafton Street, Dublin.

First Annual Report of the Medical Research Committee, 1914-1915. Cd. 8101. Price 3*d*., post free 4*d*.

Second Annual Report of the Medical Research Committee, 1915-1916. Cd. 8399. Price 3½*d*., post free 5*d*.

Third Annual Report of the Medical Research Committee, 1916-1917. Cd. 8825. Price 6*d*., post free 7*d*.

Fourth Annual Report of the Medical Research Committee, 1917-1918. Cd. 8981. Price 4*d*., post free 6*d*.

Special Report Series

No. 1. First Report of the Special Investigation Committee upon the Incidence of Phthisis in relation to Occupations.—The Boot and Shoe Trade. Price 3*d*., post free 4*d*.

No. 2. Report of the Special Advisory Committee upon Bacteriological Studies of Cerebro-spinal Fever during the Epidemic of 1915. Price 6*d*., post free 7½*d*.

No. 3. Bacteriological Studies in the Pathology and Preventive Control of Cerebro-spinal Fever among the Forces during 1915 and 1916. Price 1s. 6*d*., post free 1s. 8½*d*.

No. 4. Reports upon Investigations in the United Kingdom of Dysentery Cases received from the Eastern Mediterranean.

I. Amœbic Dysentery and the Protozoological Investigation of Cases and Carriers. Price 1s., post free 1s. 2*d*.

No. 5. II. Report upon 878 Cases of Bacillary Enteritis. Price 1s. 6*d*., post free 1s. 8*d*.

No. 6. III. Report upon recovered Cases of Intestinal Disease in the Royal Naval Hospital, Haslar, 1915-16.

IV. Report upon combined Clinical and Bacteriological Studies of Dysentery Cases from the Mediterranean. Price 1s. 6*d*., post free 1s. 8*d*.

No. 7. V. Report upon 2,360 Enteritis 'Convalescents' received at Liverpool from various Expeditionary Forces. Price 2s., post free 2s. 2½*d*.

No. 8. Report upon Soldiers returned as Cases of 'Disordered Action of the Heart' (D.A.H.) or 'Valvular Disease of the Heart' (V.D.H.). Price 1s., post free 1s. 1½*d*.

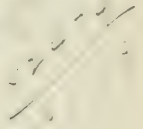
No. 9. A Report upon the use of Atropine as a Diagnostic Agent in Typhoid Infections. Price 1s., post free 1s. 1½*d*.

No. 10. The Mortalities of Birth, Infancy and Childhood. Price 1s. 6*d*., post free 1s. 8*d*.

MEDICAL RESEARCH COMMITTEE

An Inquiry into the Prevalence and Aetiology of Tuberculosis among Industrial Workers, with special reference to Female Munition Workers

Approved for publication by the Medical Research Committee, 18th October, 1918.



Medical Research Committee.

(National Health Insurance)

The Hon. Waldorf Astor, M.P. *(Chairman)*.
The Right Hon. Christopher Addison, M.D., M.P.
The Viscount Goschen, C.B.E. *(Treasurer)*.
C. J. Bond, C.M.G., F.R.C.S. (Hon. Colonel).
Professor William Bulloch, M.D., F.R.S.
Henry Head, M.D., F.R.C.P., F.R.S.
Professor F. G. Hopkins, D.Sc., F.R.S.
Major General Sir William Leishman, K.C.M.G., C.B., F.R.S.
Professor Noel Paton, M.D., F.R.S.
Sir Walter M. Fletcher, K.B.E., M.D., F.R.S.
(Secretary).

15, Buckingham Street,
Strand, W.C. 2.

Wt. 8198. 2000. 7/19. O.U.P.

AN INQUIRY INTO THE PREVALENCE AND AETIOLOGY OF TUBERCULOSIS AMONG INDUSTRIAL WORKERS, WITH SPECIAL REFERENCE TO FEMALE MUNITION WORKERS

BY

M. Greenwood, Lister Institute of Preventive Medicine, Capt. R.A.M.C. T., and A. E. Tebb, M.D., Welfare and Health Section, Ministry of Munitions.

CONTENTS

		PAGE
	Introduction	3
I.	Occupational Mortality among Males	5
II.	Industrial Morbidity and Mortality of Women	10
III.	The Regional Distribution of Mortality in England and Wales during 1911	12
IV.	The War-time Statistics in England and Wales	13
	Tables for Parts I–IV	25
V.	The Factory Conditions obtained in Birmingham in 1917	41
	General Summary of Conclusions	59

Introduction.

The history of the present inquiry is as follows. Towards the end of 1917 we learned that the death-rate from Tuberculosis, which, prior to the war, had been declining, was no longer tending to fall. We of course recognized that changes in the male death-rate shown by civilian records could not, owing to the selection for military duties of able bodied men, be regarded as of much importance or at all warrant the inference that tuberculous diseases as a whole had become more prevalent. Equally cogent objections could not, however, be urged against the data relative to women, which showed a small but appreciable increase. The war has led to the industrial employment of women upon a scale never hitherto contemplated, and it is arguable that these new conditions of life are responsible for increased incidence of tuberculosis upon the female sex.

This suggestion is to be found in Dr. Stevenson's official review of the Vital Statistics of England and Wales in 1916. He points out that the rise of mortality does not affect women of over 45. He

tion remarks that "many thousands of women are now for the first time subjected to the workshop conditions which have probably tended so much to maintain the mortality of males at working ages in recent years. Young women of the most susceptible ages have thus been subjected to risks of infection as well as of pulmonary disease predisposing to tubercle which they would have escaped in following their normal occupations; and both from this cause and from the effect of workshop conditions on women already infected a number of women have probably died who would have survived under peace conditions." It is naturally impossible to put this suggestion to a rigid test, but we have some further evidence which is in favour of its accuracy.

No English rates of occupational mortality among women are available, but the German Imperial Statistical Department published in 1910[1] an analysis of the Leipzig experience relative to the period 1887–1901. These data are exiguous enough in comparison with national records, but they cover 288,131 years of life (women) with 1,830 deaths. It was found that the death-rates for males in the various occupations were closely correlated with the known death-rates of the same occupations in England; hence it seemed likely that the rates for women were not wholly inapposite to those of our countrywomen following similar occupations.

The occupational distribution of the female population as estimated by the Board of Trade for July 1914 and January 1917 is shown in Table 4. Assuming that the Leipzig rates are applicable to these groups, we should anticipate 6,124 deaths from tuberculosis in the 1914 and 7,691 in the 1916 (or, strictly, January 1917) population. To reach the gross deaths we must assume some rate for the large balance of women not industrially employed. The lowest of the occupational rates, viz. 920 per million, has been adopted, the reason being that although the rate for domestic servants, cooks, &c. (1,970 per million) is even lower, the group here involved includes many women, such as the wives of capitalists, operatives and general labourers, whose mortality experience may be less favourable. In this way one reaches an expected total of 22,466 deaths. The actually recorded deaths were 22,214, so that the Leipzig rates applied to the estimated population in groups give us a figure only differing from the truth by 1·1 per cent. With these rates applied to the population as distributed in January 1917, we should expect 23,986 deaths in 1916; the actual figure was 24,131. Here the error is 0·7 per cent. in defect. The computed totals give rates per million of 1,177 and 1,321, which the Registrar-General's computations provide 1,164 and 1,234 per million. The calculation on the Leipzig bases would lead to an increase of 4 per cent. in the death-rate from tuberculosis between 1914 and 1916; actually there has been an increase of about 6 per cent. When it is remembered that not a few of the unoccupied balance may really have been engaged in industrial work although not under conditions which led to their inclusion in the Board of

[1] [illegible]

[2] [illegible]

Trade's statistics, the concordance between the mortality calculated upon the basis of the Leipzig rates and that actually experienced is sufficiently close to lend support to Dr. Stevenson's suggestion that a principal factor is industrial reorganization.

Accepting then, as a working hypothesis, the view that the increased incidence of fatal tuberculosis upon women is a result of industrialization, it follows that a detailed investigation of the mediate factors is an appropriate task for the Medical Research Subsection of the Ministry of Munitions. This report describes the work so far accomplished

The inquiry has been participated in by the following members of the Subsection. Capt Greenwood and Misses Thompson and Woods have carried out the statistical analysis. Dr. Tebb has had charge of field inquiries and most of the experimental work. In experiments at the head-quarters laboratory of the Subsection Capt. Greenwood and Dr. Tebb have co-operated.

Valuable assistance and advice have been received from the Director of the Welfare and Health Section, Dr E. L. Collis, while special thanks are owing to Dr. Leonard Hill, F.R.S., who has kindly permitted both Dr. Tebb and Capt. Greenwood to profit by his personal instruction in the experimental methods utilized.

The report is divided into the following parts:

Part I deals with Occupational Tuberculosis as revealed by the Statistics of Male Operatives, the principal data utilized being from the Registrar-General's decennial supplements including the unpublished data for 1910-12, for the use of which we are indebted to the courtesy of Dr. Stevenson. In this part an attempt has been made to deal with the factor of selection

Part II is concerned with the occupational morbidity and mortality of women. Owing to lack of trustworthy data this section is incomplete.

Part III examines the regional distribution of mortality in England and Wales during 1911.

Part IV examines the war-time statistics of England and Wales.

Part V is a general account by Dr. Tebb of factory conditions as observed in Birmingham in 1917.

Part I. Occupational Mortality among Males.

It is not proposed to discuss the general divergences of either mortality or morbidity which differentiate class from class except in so far as they are connected with variations of the incidence of tuberculosis upon different occupations

In certain instances the objective explanation of such variations has been definitely ascertained. Examples are afforded by the prevalence of maladies directly due to the absorption of lead and by the incidence of pulmonary disease upon the practitioners of certain crafts which lead to the inspiration of special forms of mineral dust. The former instance is a commonplace of medico-

industrial literature, while the latter is the subject of a recent monograph by E. L. Collis,[1] who has proved it to be due to the action of silica particles and to be characterized by an age incidence unlike that observed in other occupational groups or in the population as a whole.

Leaving out these special and well-defined groups, we still observe wide variations of mortality in general, and phthisis mortality in particular, amongst the occupational groups. For instance, the death-rate at ages 25–35 (years 1900–2) from phthisis of males employed in agriculture was 1·10 per 1,000 living, of fishermen 1·40, of shipbuilders 1·53, and of shoemakers 3·27. We have to account for these great differences.

Broadly speaking, we may enumerate the following possible factors:

Industrial Selection.[2] Since the type of physique which would suffice for work in a boot factory would be inadequate to the task of a shipwright, we must expect to find stronger and more vigorous men in shipyards than in boot factories. Consequently we should expect to find the death-rate of shoemakers higher than that of shipbuilders even if their occupations in themselves were equally hygienic.

Industrial Status. Under this heading we have to record the fact that occupations making equal demands upon the physique (and, perhaps, mental powers) are not equally well remunerated. Professional football players and ploughmen among the open air occupations, commercial clerks and higher division civil servants, among sedentary workers, are illustrations. Since the higher the remuneration of the employed person the greater has opportunities of securing an hygienic home environment, it follows that status must powerfully bias the mortality or morbidity rate of any occupation.

The Industrial Environment itself. This last cause group is the one we specially desire to unmask. The first group is hardly at all, the second but partially, while the third would be very largely amenable to administrative control if only we knew in what direction such control should be exercised.

To attempt to isolate the effects due to each of these three great groups of causes upon mortality or morbidity as a whole is an undertaking which might daunt any inquirer. The task we are set, although sufficiently formidable, is perhaps less unpromising. We propose to study not mortality as a whole but that fraction of it attributable to one disease only, viz. to tuberculosis. This limitation suggests a plan which should if successful diminish the influence of the first and second cause groups, which do not come within our proposed scope. The plan depends upon the assumption that the death-rate from all causes *except tuberculosis* might be a proper measure both of industrial selection and status.

[1] M'Kay Lecture on Industrial Pneumonoconiosis, [illegible] 1915.

[2] [illegible] that fair hair was invented by "modern" [illegible] [illegible] [illegible]

We know that, in the mass, the robust die at a lower rate than the weaklings, that also the rich die at a less rate than the poor. In statistical language, the function which measures physique and the function which measures status are each correlated with the death-rate from all causes. If then we exclude the death-rate due to tubercle, the residue will still be some measure of status *plus* physique unless tuberculosis is the only disease which secures more victims among the poor or weak than among the wealthy or robust. Regarding then the death-rate from other causes as a measure, we shall expect to find correlation between it and the rate from tuberculosis, and can construct a regression equation to predict the tuberculosis rate, having been given the rate from other causes. Should we find that in any particular occupation the tuberculosis rate actually observed is much in excess or defect of that predicted from the non-tuberculous death-rate, we infer that the occupation in question may afford special opportunities for acquiring or offer special barriers against the development of the disease over and above the general factors. This reasoning must be criticized with severity before we accept it. We will take first a purely analytical objection. Should the regression of the tuberculosis death-rate upon the non-tuberculosis death-rate be non-linear, in other words should the relation of the two not be satisfactorily represented by a first degree equation, the latter cannot be expected to afford a good basis of prediction, and the consequent discrepancies between prediction and observation will be of small practical importance. This criticism can be met. We took for testing, the standardized rates for tuberculosis in the occupations studied (these are listed in Table 2) as shown in the returns for 1890-2, 1900-02, 1910-12, providing 178 observations for the two death-rates. For this set the correlation coefficient (r) was 0·656 and the correlation ratio 0·692, which tested in the ordinary way shows no sensible departure from linearity. Hence we are to infer that the simple regression equation is probably a suitable basis of prediction.

The next question is whether the death-rate from other causes than tuberculosis is a suitable measure of the combined action of physique and status as apart from industrial environment. We think that it cannot be disputed that the non-tuberculous death-rate is highly correlated with the sum of these factors, is some measure of their combined working, but it is certainly not true that tuberculosis is the only disease that is affected by the factory environment itself. Evidently a great source of error would be present if we included in our survey any occupations, such as pottery work or painting, liable to special *industrial* risk of non-tuberculous disease, and these have been carefully omitted. On the same account we have omitted all occupations having a similarly direct occupational risk of phthisis (such as Silica-working). These omissions simplify the problem, but the objection subsists that the non-tuberculous death-rate is not only a function of the physique and status but is in part a function of the immediate factory environment, there is the further objection that the phthisis death-rate may be *more* closely correlated with physique and status than is the death-rate from other causes. Hence we

must conclude that the sorting out of occupations by the present method can do no more than indicate the occupations peculiarly liable to phthisis or specially immune from it, and does not give a complete statistical account of the matter. Inasmuch, however, as it does pay attention to and allow for the mortality due to other causes it is at least a step in the right direction.

A more subtle criticism is the following. Infection precedes death, sometimes at a long interval. If the sufferers from phthisis are eliminated from industry at an earlier stage of disease than those affected by some other malady, the correlation of *death*-rates does not exhibit the full stringency of the relation. We have no evidence in favour of or against this hypothesis, beyond what is afforded by an analysis of the data in age groups, consequently we can merely note it and import some additional reserve into the arguments based upon our results. We believe, however, that popular fear of working in association with phthisical subjects is so recent a phenomenon, and even now so local in its influence, that we have no warrant for putting much practical weight upon the objection. We must however record the opinion shared by us with all other statisticians that industrial mortality rates are very insecure foundations for elaborate arguments. We are not here alluding to the question of so-called spurious correlation in rates, which is not in our judgment of importance in the present application: we are thinking of the much more serious difficulties associated with (*a*) ambiguities of classification by occupational groups, (*b*) the real numerical strengths of the populations at risks and the consequent weight assignable to particular death-rates. Neither of these serious difficulties can be adequately appraised with the help of the information published or otherwise obtainable.

We shall now review the results due to the employment of our method. The data first to be examined are those for standardized death rates (all ages). We have used the Registrar General's decennial figures for 1890-2, 1900-02, 1910-12 and the special report of the Central Bureau of Statistics in the Hague on the Netherlands experience 1908-11.[1] The first two and the fourth of these collection of data refer to pulmonary tuberculosis; the MS. return for 1910-12 kindly supplied by Dr. Stevenson relates to Tuberculosis in general but, owing to the age limits, will mainly comprise deaths from pulmonary tuberculosis. Tables 2-4 show the occupations studied and the various statistical constants and equations.[2] In Table 4 we give the results of our method of elimination. + against a group means that that group experienced an amount of pulmonary tuberculosis 25 per cent. or more in excess of the figure predicted from its death-rate for other causes; − means similarly that its death-rate from tuberculosis was in defect of the prediction to the extent of 25 per cent. or more.

We note that there are eight groups having an excess at each decennial group of the English statistics, while four of these are

[1] [illegible] No. 217 's Gravenhage, 1913.

[2] Since these equations are used as mere interpolation formulae we have not thought it necessary to discuss the probable errors of the various constants.

also in excess in the Dutch data. The four occupations which thus receive the highest possible number of bad marks are Bookbinders, Printers, Tailors, and Cabinet makers. Hatters, Hosiery-makers, Shoemakers, Hairdressers receive 3 bad marks in the English records, but Hairdressers are actually below the expected figure in the Dutch experience. Woodturners and Coopers have had excess of phthisis in the last two English decennia and in Dutch experience. At the other end of the scale we have six occupational groups showing 25 per cent., or greater reduction on the predicted value, viz. Farmers, Fishermen, Maltsters, Chemical Manufacturers, Plate-layers, Brick and Tile-makers.

Tables 5 and 6 are concerned with the application of the method to certain age groups in the different occupations. These special groups were chosen on account of the researches made by Brownlee.[1] Brownlee was led by the statistical investigation of the regional data for phthisis mortality provided in the decennial supplements of the Registrar-General to infer that epidemiologically phthisis is a threefold disease. One type specially causes death among the young, a second leads to death in middle life, the mode occurring about the age of 47 years, while a third type affects persons in old age. Brownlee also concluded that the second type was much more sensitive to environment than the first and third, which might perhaps be each due to the same strain of organism. If we accept this hypothesis provisionally it would follow that an excessive mortality in the age group 35–45 is of more significance from the environmental point of view than at an earlier or later age. Of our four black-listed occupations, Bookbinders and Printers show excess at each of the three age groups used. Tailors have no excess between 55 and 65. Cabinet-makers are only excessive at ages 35–45. From these results we seem entitled to infer that the factory conditions of Printers, Bookbinders, and Tailors are specially unfavourable, because, although they have suffered an excessive mortality in the youngest age group and are therefore to that extent select, the toll is still abnormal at ages 35–45. Cabinet-makers, on the other hand, not having been weeded out to the same extent in earlier life might experience an excessive middle-age mortality although the environmental conditions were normal. It must however, be frankly recognized that this argument is precarious. Those at ages 35–45 are not the survivors of ages 20–25, but contemporaneously existing operatives. To meet this criticism we might deal with the ages of an earlier decennial supplement. But owing to late entrance to a trade this expedient is not entirely satisfactory. We have, however, made an attempt in this direction. The death-rate from phthisis in the age group 35–45 for the occupations was brought into relation with (*a*) the death-rate from all other causes except accidents and suicides for the same age group (decennial supplement 1900–2), and with (*b*) the death-rate from all causes for the age group 25–35 in the decennial return for 1890–2. The regression equation connecting the phthisis death-rate with the two other variables was then calculated. Two

[1] Report to the Medical Research Committee, Special Report Series, No. 18.

occupations as I had to, viz numbers 103 and 104 had to be omitted as they were not subdivided in the previous decennium. The resulting equation (Table 7) was not found to give predictions materially different from those based upon contemporaneous mortality alone. As remarked above the death-rate ten years earlier in an occupation among employees then aged 25-35 is not a satisfactory measure of the mortality experienced by the group of persons from whom the operatives aged 35-45 in this decennium are derived, because of changing occupations. Still it is some measure of their conditions (the correlation between mortality at ages 25-35 in the decennium 1880-90 and that at ages 35-45 in the following decennium is high), and since its use hardly lessens the regression equation as a means of prediction we seem entitled to infer that there really is a large occupational-environmental factor in the causation of phthisis. It would of course be practicable as a mere matter of arithmetic to extend this method, taking into consideration yet other variables. But the material objections to which we have above alluded deprive any such extension of so much of its apparent interest as to leave behind hardly sufficient to repay the labour of calculation.

The conclusion to be drawn from the analysis is, we think, that in certain occupations not exposed to a specific industrial risk of phthisis, the incidence of this disease is still too heavy to be explained as a by-product of inferior physique independent of the factory environment itself.

Part II. Industrial Morbidity and Mortality of Women

The statistical data relative to industrially employed women which have been published are meagre in the extreme. This is in part due to the fact that the employment of women in some industries is a phenomenon of recent times. A more important factor is the limited length of the average industrial life of women, consequent upon the fact that in any country a considerable majority of the female inhabitants marry and thereafter cease to figure as industrially employed persons. For these and other reasons which we need not detail, the English official statisticians—who have provided us with by far the best industrial mortality records for men—have not been able to deal with the statistics of females on similar lines, and such information as we have is derived from continental sources. Tables 9-12 summarize data collected by Prinzing[1] and Koelsch[2] while Table 8 has been constructed from the information contained in the Leipzig Krankenkasse report of which use was made above. This last table is the most extensive, but, in comparison with a national record, it is obviously imperfect. From our present point of view the heavy incidence of tuberculosis upon tobacco factory hands, cigar-makers, metal workers and basketmakers is of interest. It will be noted that the Austrian figures (these are death not morbidity rates) also put the tobacco-workers in an unfavourable light.

[1] [illegible], J. no. 1906.

[2] [illegible] by Mayet and Fürstenberg, vol. 1, March 1912, ed. by Koelsch [illegible]. Koelsch's figures are [illegible].

The occupational classification imposed by the sources and nature of the material is so different from that used in Part I that comparisons are difficult to make. Our black-listed occupations for males were bootmaking, printing, tailoring, and cabinet-making. So far as tailoresses are concerned their morbidity from tuberculosis is not excessive, but in comparison with their sickness from all causes it is somewhat higher than might have been anticipated. In other words, their experience is qualitatively similar to that of males, but quantitatively much more favourable. Neither cabinet-makers nor printers as a whole can be compared with any of the female occupational groups. The boot and shoe factory hands are a small group in the Leipzig records; they contrast sharply with the males, for their tubercle morbidity is definitely below the average and to about the same extent as their morbidity from all causes. This is not an important Leipzig industry. At all ages 11,641 years of male life with 120 cases of tubercle and 1977 years of female life with 11 cases are recorded.

Evidently it would be rash to draw conclusions from such small numbers. It is also clear that comparisons are dangerous owing to the troublesome difficulty of selection, which dogs our steps throughout such inquiries. For instance, the superior position of women in the shoe industries, if any superiority were found on examining large collections of data,[1] might be attributed to selection by many people. Owing to the average woman being less muscular than the average man, a trade which need not recruit the physical *élite* of the men might need the strongest of the women if men and women did the same work. In other words, the female shoe hands might be better physical specimens of womanhood than the male hands of manhood. Similarly, the economically inferior position of women and their practical exclusion up to quite recent times from some of the most highly skilled crafts, leads to the necessity of considering a different scale of values of status.

We are not in a position to determine the validity of these criticisms, but they are of sufficient weight to deprive us of any right to draw definite conclusions from the statistical data provided. The only other investigation which could be carried out on the basis of these figures was to measure the association between tuberculosis and various other diseases. The results are shown in Table 13. It does not seem that any other index than the death or (as here) morbidity rate for all causes other than tuberculosis is superior to such rate for the present inquiry. We had rather hoped that the correlation of tuberculosis rates with cardiac diseases would be high, because in valvular disease of the heart over-exertion is a common and well known cause of death or incapacity. Hence invalidity or death from this group of diseases might possibly be some measure of the amount of muscular exertion, and would, if highly correlated with the tuberculosis rate, help us to bring the latter into relation with over-strain. The result, however, both from these and other data has not been sufficiently distinct to warrant

[1] No evidence of any sexual distinction was detected by the Second Investigation Committee of the Medical Research Committee which reported upon the boot and shoe industry in 1915.

practical conclusions, the correlation being non-significant with regard to its probable error.

On the whole the general statistical data regarding women in industry are very disappointing in scope and we have therefore had to rely almost entirely upon our own observations. On this account we do not here attempt any general discussion of the subject.

Part III. The Regional Distribution of Mortality in England and Wales during 1911.

For a study of the regional mortality of tuberculosis in this country it might possibly have been expected that the notification data would have been useful. In truth however they are almost valueless. We have spent much time in collating the returns made to the various medical officers of health and published in their annual reports during the last few years and find ourselves in complete accord with the opinion frequently expressed by the medical officers, viz. that the numbers of notified cases do not at present give any real idea of the distribution of the disease and that the rates are not even useful indices of comparison between district and district. To enforce this we provide in Table 14 a summary of the less evidently incomplete returns from which it will be perceived that both the fluctuations from year to year in the ratios of deaths to notifications and the wide range of variation from district to district are enough to deprive the notifications of any right to be regarded as measures of true prevalence. Whether notifications of a chronic and not highly infectious disease such as tuberculosis will ever attain the measure of accuracy reached in the zymotic diseases returns (which are themselves in the view of many good observers by no means exhaustive) is a matter of doubt; certainly that point has not yet been attained. We shall not, therefore, again refer to notification statistics in general; some notes on the Birmingham figures appear later on. With respect to the problem of regional distribution, Dr. John Brownlee of the Medical Research Committee has recently undertaken a full analysis which was passing through the press at the time this section of our report was being drawn up. Many of his conclusions are of great importance and some are directly relevant to our inquiry. We have looked at the matter from a different angle and our results are to some extent complementary to certain of his.

It is well known that tuberculosis is more prevalent in towns than in the country and we have no need to encumber our report by citing statistical proofs of the proposition. It is however, material to learn whether the disadvantage of the towns in this respect is decidedly greater than with regard to mortality from other causes, because the total mortality rate of the rural districts is also less than that of cities. To test the point we considered the distribution of the female population at ages 15–45 and the mortality from pulmonary tuberculosis and from all other causes at these ages for the year 1911. The correlation between the

mortality from pulmonary tuberculosis and from all other causes was then computed for the metropolitan and country boroughs, for the aggregates of urban districts, and for the aggregates of rural districts. The results are shown in Table 15. It will be seen that the correlations are in descending order of magnitude, passing from rural through urban down to county and metropolitan boroughs. As the departure from linearity, tested by the correlation ratio is rather greater among the metropolitan and county boroughs than in the rural districts, the difference in stringency of correlation between the two extremes is somewhat exaggerated by a comparison of the coefficients of correlation; it is however considerable. If we now sort out from among the metropolitan and county boroughs those which are the seats of great industries, we retain 33 such centres and the correlation falls still further down to 0·33. For men of the same ages the absolute values of the correlations are smaller but the contrast remains, the value being 0·360 for rural districts and 0·103 for industrial towns.

This regional study then confirms the findings of our industrial analysis, viz. that some factor other than selection by physique is important in leading to the genesis of pulmonary tuberculosis. We must note that the age grouping used is not the one we should have chosen had the work been commenced after a study of Dr. Brownlee's paper; the results are blurred by geographical mixture. Nevertheless in broad outline the statement just made seems to be correct.

We conclude then, that the incidence of phthisis upon town dwellers is greater than can be accounted for by the general lowering of health associated with urban conditions and is consistent with the view that industrial employment introduces a special factor which makes for the development of tuberculosis, an inference harmonious with those of Part I.

It does not appear to us certain that domestic overcrowding can be a sufficient explanation of the divergences because *a*) domestic overcrowding is well known to be very gross in many rural districts, and *b*) the investigations described in the ensuing section do not suggest that domestic overcrowding can, at least statistically, be convicted as the prime offender.

Part IV. The War-time Statistics in England and Wales.

The data for rendering a statistical account of tuberculosis in war-time are generally meagre. In the first place we have to confine our attention to the female sex; the calling to the colours of a large proportion of able-bodied males has altogether deprived the civilian rates of mortality of any important significance in this matter, those males still within the scope of the Registrar General's statistics are a physical selection, or rather rejection of males as a whole. In the second place, when dealing with both males and females we are deprived of the assistance usually rendered by an approximately exact knowledge of the population at ages exposed to risk.

The one datum which remains to us is a knowledge of the deaths at ages and their causes and what we have now to consider is the value of this information as measuring the incidence of tuberculosis upon a population. The question is Given a knowledge of the total deaths occurring between certain age limits and the number of such deaths attributed to a single disease for each of a series of groups how far do fluctuations of the ratio of deaths due to the specified disease to all deaths at that age or if we prefer it, the ratio of deaths from the specified disease to all other deaths, measure fluctuations of *incidence* of the disease in question At first sight it appears that such a ratio which is termed the *proportionate mortality*, is of little value because it is easy to imagine cases in which its value decreased when the real incidence of the disease increased or vice versa. For instance suppose that the death-rate from phthisis were increasing but not increasing so rapidly as the death-rate from other causes, then the ratio would be decreasing. Suppose again that one were comparing the proportionate mortalities from phthisis in a series of towns the data being contemporaneous (thus excluding any secular trend). Suppose the actual incidence of phthisis per 1000 living in the investigated age group were really identical in all towns then if certain of them suffered heavily from say, epidemic typhoid, others contained miners from pits which had experienced serious accidents the proportionate mortalities would differ greatly. As possible sources of error these instances must be admitted, indeed, as a mere matter of simple logic, we could not expect to derive as much information from a knowledge of deaths *alone* as from a knowledge of deaths *and* populations. But it would be a gross error to discard a method because it admittedly possesses weak points. Let us look at the other side of the matter. Suppose the rate of mortality from diseases other than those that we were studying were strictly constant, then the ratio of deaths from the special disease to other deaths would be a complete measure of the former's varying incidence. Under such conditions the population at risk would be known, it would be merely the deaths from other diseases multiplied by some constant. Now it is probably true that the death-rates from diseases other than tuberculosis are in certain age groups much less variable than those from phthisis, but the absolute variability is still so high that the hypothetical case is unrealized. The suggestion, however, presents itself that we should directly test the value of a proportionate mortality index by comparing it with the age death-rate in a series of groups where both figures can be computed. This was done by Collis[1] for a series of occupational groups and he found that there was a general correspondence between the proportionate and the true mortality, where one was above its average the other was too. We have probed the matter further. In the first place we used the occupational groups which have appeared so often in our analysis, viz. ages 35–45 of the decennium 1890–1900 and calculated the correlation between the

[1] [illegible] M.A. Lecturer in Logic in Pharmaceutical [illegible] p. 29; also Collis's [illegible] Report, Committee on Medical Benefit, Cd. 1478, pp. 181 and 82.

ratio of deaths from phthisis to deaths from other causes and the death-rate from phthisis. The results are given in Table 17*a*. The correlation is considerable, but as the number of observations was insufficient to construct a correlation table we could not satisfactorily measure the degree of accuracy attained by a linear regression equation in predicting one variable from the other. To this end a series of districts was taken from the decennial report the criterion being that the mean population at risk should be at least 50,000. In each case the ratio of phthisis deaths to remaining deaths at ages 35–45 and the phthisis death-rate at that age were computed and the two values correlated in the ordinary way. The complete analytical results are shown in Tables 16 and 17 *b*.

These investigations lead to the following results:

(1) There is a substantial correlation between the ratio of phthisis deaths to deaths from other causes within the age group and the actual mortality rate from phthisis at that age group.

(2) The regression of the death-rate upon the proportionate mortality is effectively linear.

(3) Hence from a knowledge of the proportionate phthisis mortality within a group of districts we should reach a fairly accurate prediction of the difference between the average mortality rate for that group of districts and the general average mortality.

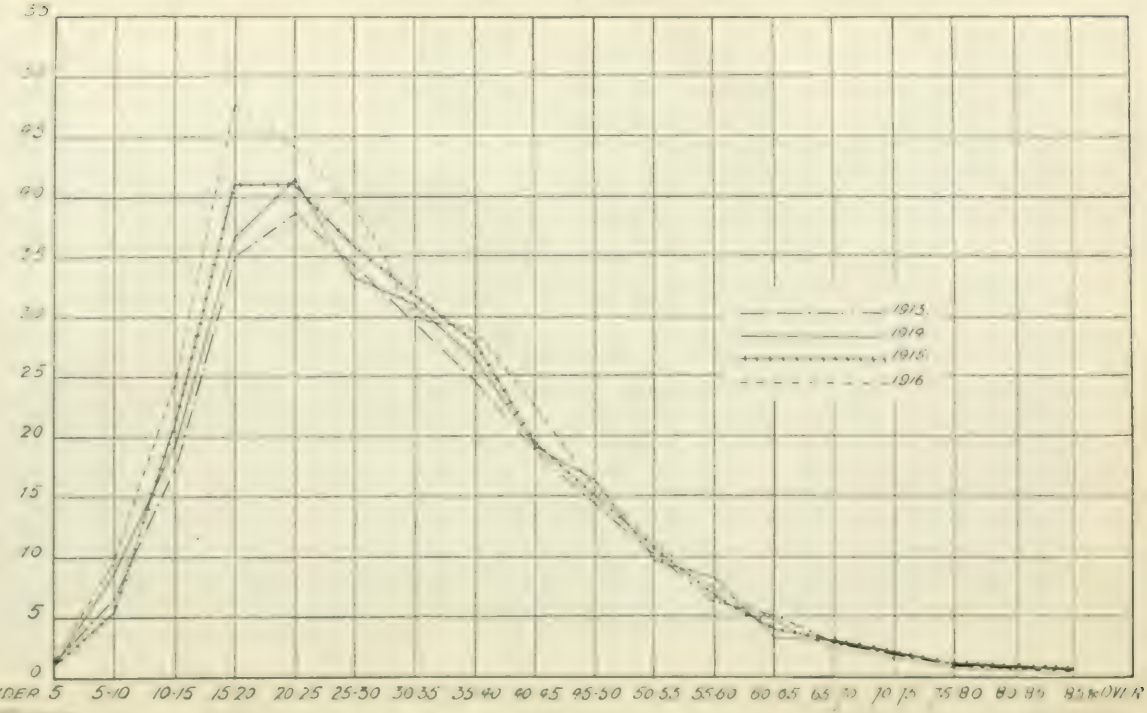
(4) But the correlation is not nearly high enough for the prediction of the death-rate *in any individual case* from a knowledge of the proportionate mortality to be within narrow limits on either side of the true value. It is likely to be a very poor approximation.

The practical inference is that much risk of error is incurred when we substitute proportionate mortalities for rates of mortality in our reasonings anent the incidence of tuberculosis. We must go no further than to conclude that when in a group of districts the average ratio shows an increase then the absolute death-rate for these districts has also increased. This important reservation having been made, we turn to the recent data of phthisis which are expressible merely as ratios.

Tables 18 and 19 contain the ratios of phthisis deaths to deaths from other causes among women aged 15–45 in all administrative units for each of the years 1913–16 inclusive. In Table 18 are contained those districts in which the 1916 ratio is greater than the 1913 ratio, in Table 19 those in which it is not greater. For the sake of completeness all areas have been shown but many of them are so small or thinly populated that the actual ratios are unreliable, one or two deaths more or less influencing the ratio seriously. Confining ourselves to the county and metropolitan boroughs it appears that 29 showed a lower ratio in 1916 than in 1913, 74 showed an increase.

There is some evidence (Table 20) that the proportion of areas showing an increase of the ratio is larger among industrial towns than elsewhere. But the classification is difficult and may even seem capricious while the contrast between the groups named is not very striking. In order to get to closer quarters with the problem the proportionate mortality (in this case the ordinary proportionate

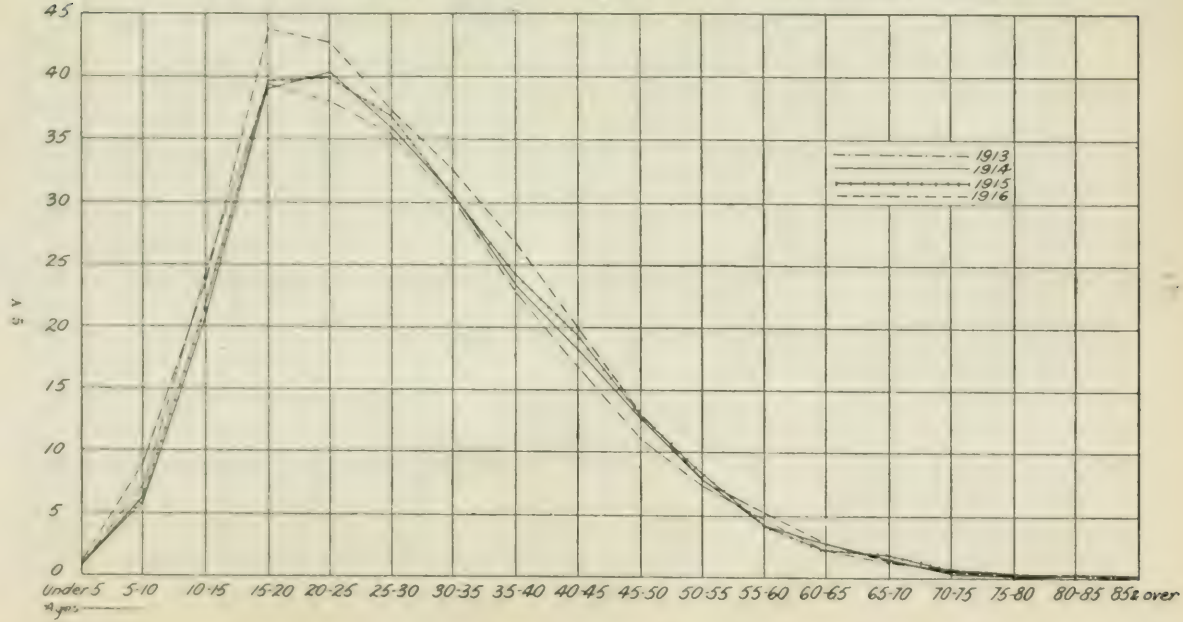
Deaths from Phthisis expressed as Percentages of Deaths from all Causes (Women)



AGGREGATE OF COUNTY BOROUGHS

DIAGRAM 2

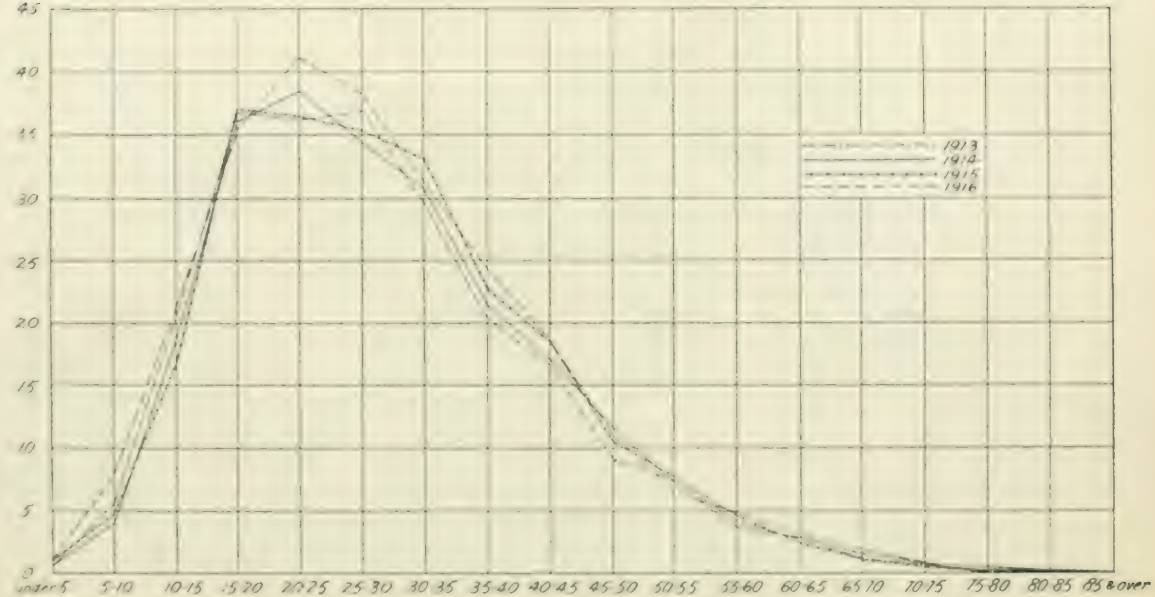
Deaths from Phthisis expressed as Percentages of Deaths from all Causes (Women)



AGGREGATE OF RURAL DISTRICTS

DIAGRAM 3

Deaths from Phthisis expressed as Percentages of Deaths from all Causes (Women)



mortality, viz. ratio of deaths from phthisis to deaths from all causes at each age) amongst women was plotted in diagrammatic form. Diagrams 1, 2, and 3 show the course of events in the County of London, the County Boroughs, and the aggregate of rural districts for each year from 1913 to 1916 inclusive. It will be noticed that London and the aggregate county boroughs show a considerable and fairly uniform increase of proportionate mortality at ages 15–20 and 20–25, particularly in the earlier quinquennial group, from 1913 onwards. The former peak is not seen in the rural experience. The differences were sufficiently striking to merit special consideration. To that end Dr. Stevenson has kindly supplied the detailed figures from the following towns which we selected, on the advice of Dr. Collis, as representative of different types of community:

(*a*) Cotton towns. Blackburn and Oldham.

(*b*) Metal towns and towns greatly affected by war work. Birmingham, Coventry, Manchester, Newcastle, Sheffield.

(*c*) Industrial towns less directly affected by war conditions. Ipswich, Stoke-on-Trent, Norwich, Worcester, York.

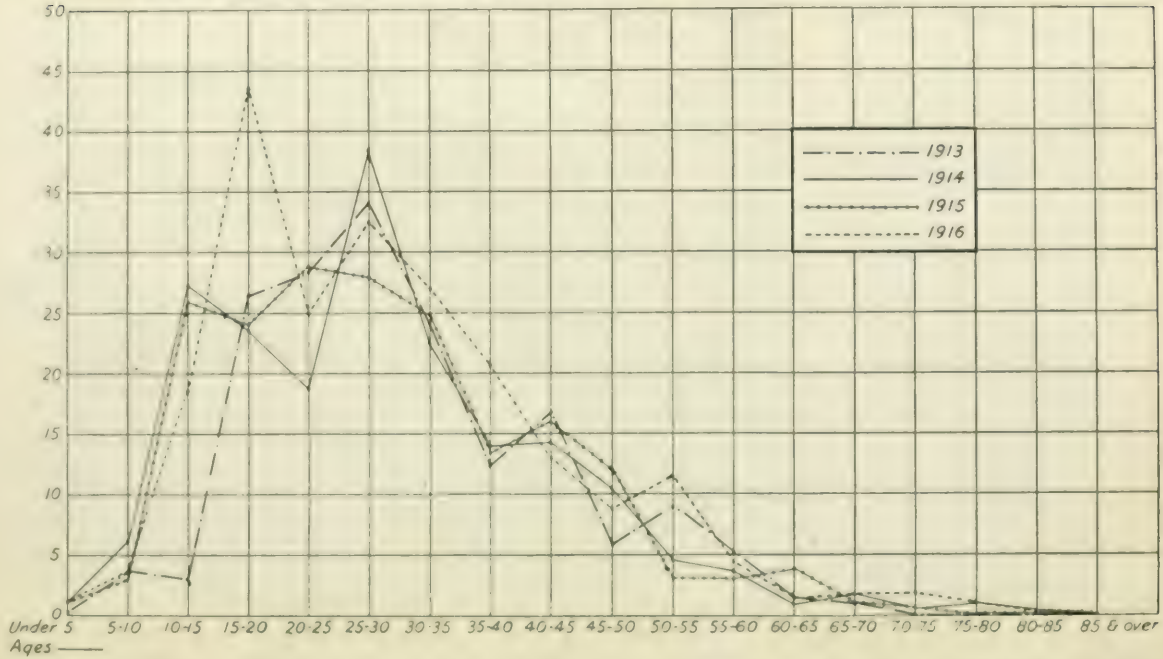
(*d*) Non-industrial towns. Bournemouth, Brighton, Oxford, Great Yarmouth.

Diagrams 4–7 show the position in each of these groups.

Groups (*a*) and (*b*) agree in the rise at age 15–20. There is a discordance at ages 25–30, where group (*a*) shows a fall. After age 30 the 1916 proportion remains for some time above the level of the other years in both classes. In the group of old-established industries (*c*) the increase at ages 15–20 has not advanced steadily from year to year, but there has been such a steady rise in the next quinquennium, viz. from 20–25.

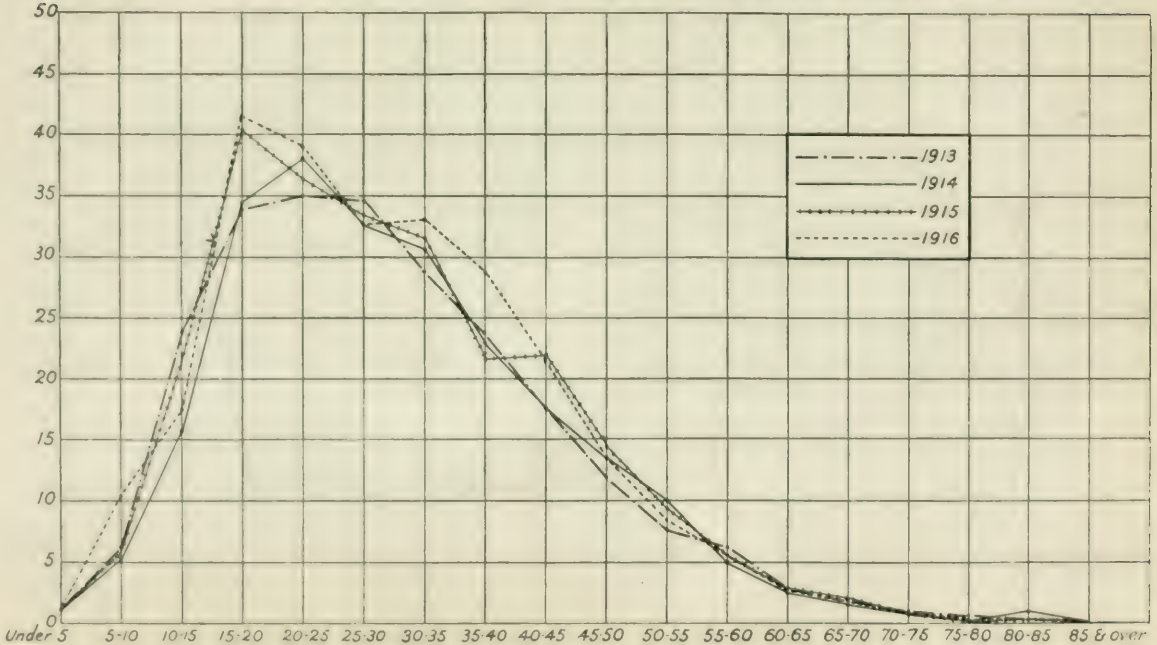
Group (*d*) contrasts with the industrial towns. There is not an increase but a decrease of the proportionate mortality at ages 15–20, combined with a great elevation at ages 30–35 in the year 1916. Before commenting upon these figures, we must note that statistically they are not equally reliable; in particular the aggregate population of the last group is so much smaller than those of the others that the proportionate figures are *ab initio* suspect owing to errors of sampling and record. Still, making these reservations, it must be said that the curious phenomenon of rising proportionate mortality in the large industrial towns and London at age 15–20 since the war is in need of explanation. The causes of mortality from other diseases at this epoch of life are not numerous nor subject to the considerable fluctuations dependent upon the infantile zymotics. No doubt something can be attributed to the smaller amount of migration to the famous health resorts (which might account for the actual decline of proportionate mortality at this age group in such places as Brighton and Bournemouth), but this can hardly be a sufficient account of the phenomenon when we remember the relative sizes of the populations under notice. The obvious suggestion that the great cities have drawn upon the weaklings of the rural areas (which areas, as seen in Diagram 3, show no increase of proportionate mortality at this quinquennium) seems difficult to avoid. Such a conclusion is compatible with our original surmise

Deaths from Phthisis expressed as Percentages of Deaths from all Causes (Women)

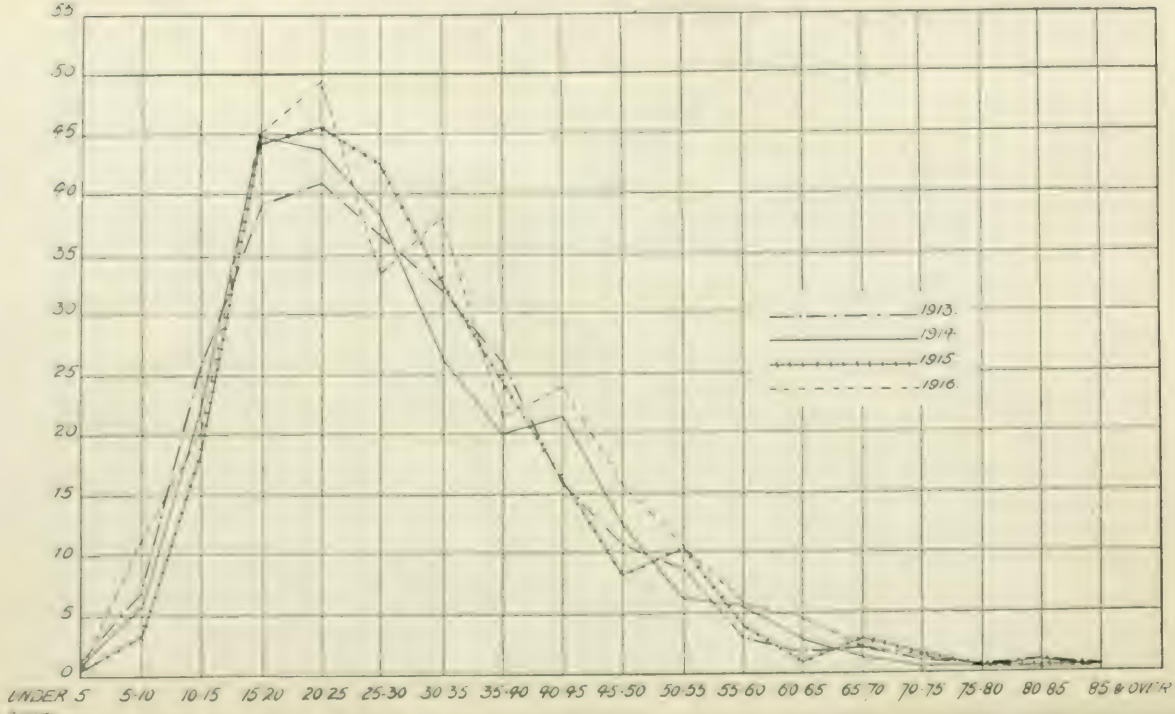


BIRMINGHAM, COVENTRY, MANCHESTER, NEWCASTLE, AND SHEFFIELD

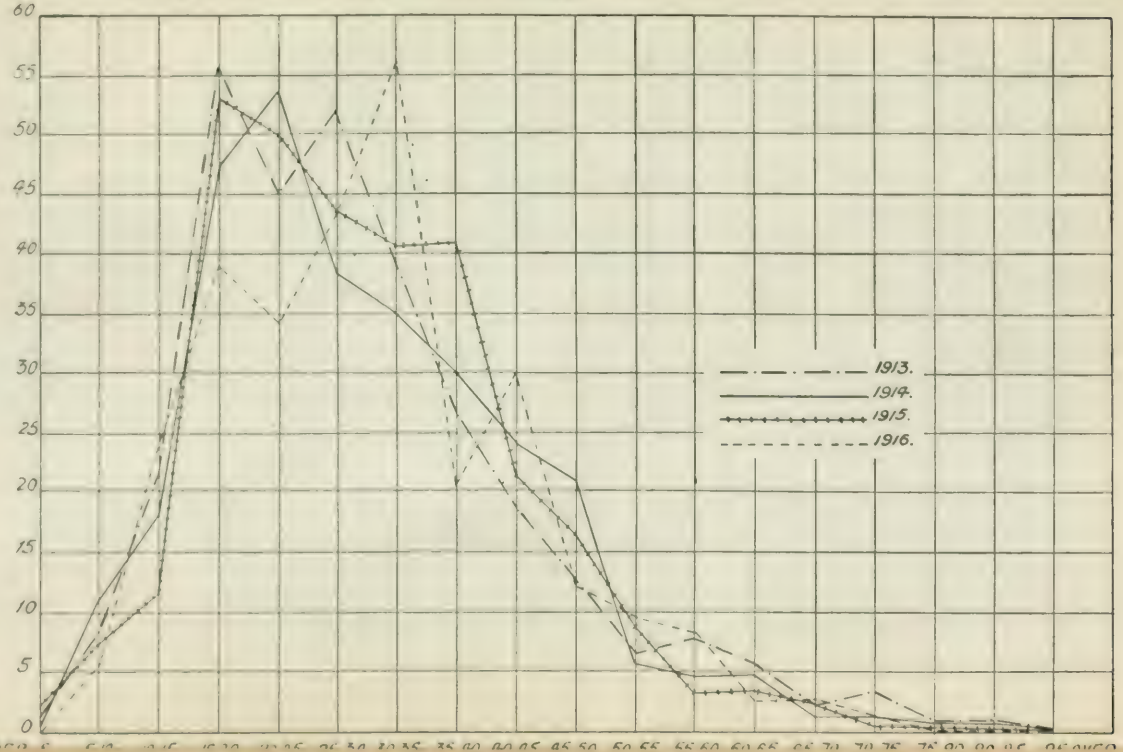
Deaths from Phthisis expressed as Percentages of Deaths from all Causes (Women)



Deaths from Phthisis expressed as Percentages of Deaths from all Causes (Women)



Deaths from Phthisis expressed as Percentages of Deaths from all Causes (Women)



that the war-time increase does depend upon industrialization. We have not, however, been able to provide any other statistical confirmation of this. As mentioned before, we thought that the correlation between mortality from cardiac disease and that from phthisis might be helpful on the assumption that the former would be some index of overstrain. As noted above, however, this surmise is not borne out by analysis of industrial statistics and in any case direct computation showed that the correlation between the two *proportionate* mortalities has not changed since the war. Another suggestion was to deal separately with the various districts, assigning to each an index of its industrial character determined from the 1911 census of occupations. In this way it seemed possible to differentiate machine towns, cotton towns, &c., from other industrial centres. The result, however, of a long and elaborate series of calculations has proved negative. We did indeed arrive at ostensibly large correlation between certain of the variables, but none of these coefficients bore such a ratio to its estimated probable error as to entitle us to use it for drawing practical inferences, and we do not think it justifiable to burden the report by citing the particulars. We have now brought together all the information of a purely statistical character which we have thought to be both fairly reliable and relevant to the issue. We have not dwelt upon the relations between phthisis mortality and domestic overcrowding, not because we doubt the importance of this matter, but because we can cite no data which might be deemed perfectly in point. We did not indeed find any relation whatever between the changes of proportionate mortality and the housing standard as appraised in the 1911 census,[1] but this negative finding proves nothing, since, owing to the redistribution of population due to the war, a 1911 index may have no value when applied to a 1916 population.

In Part V will be found the descriptive account of war-time conditions ostensibly relevant to the issue which formed part of our original programme. This account supplements the statistical data; it was not written originally to form part of a co-operative paper and there is consequently a certain amount of overlapping. As, however, the record of an eyewitness loses vividness when it is altered, we have thought it best to allow it to stand almost as it was written by one of us (A. E. T.) after visiting the area studied.

[1] I.e., over-crowded towns have not deteriorated from the point of view of phthisis more than the rest.

Tables for Parts I—IV.

Table I. Women in Industries.

Industry.	Approximate Number, July, 1914	Approximate Number, June, 1917	Tuberculosis Death-rate per 1,000 of Equivalent Class at Largest.	Expected Deaths, 1914.	Expected Deaths, 1916.
Metals	170,000	444,000	4·04	686·8	1,789·7
Chemicals	40,000	82,000	3·13	125·2	256·7
Textiles	863,000	884,000	2·80	2,416·4	2,472·4
Clothing	620,000	582,000	2·35	1,457·0	1,367·7
Food	196,000	224,000	2·20	448·8	513·0
Paper and printing	147,000	141,000	2·71	399·7	383·5
Wood	14,000	63,000	2·26	99·4	142·4
Commerce	196,000	773,000	0·90	191·0	705·3
Residue	16,507,132	16,402,000	0·09	16,342·0	16,145·0
Total of Expected Deaths				22,440·0	23,986·0
Total of Observed Deaths				22,214·0	24,131·0

Table 2. Occupations with their Reference Numbers used for Correlation.

Ref. No.	Occupations.
15.	Carman, carter, &c.
16.	Bargeman, lighterman, waterman
17.	Seaman, &c., merchant service.
18.	Dock labourer, wharf labourer
20.	Farmer, grazier, farmer's son, &c.
21.	Farm labourer, farm servant
22.	Gardener, nurseryman, seedsman
23.	Fisherman
24.	Maltster.
25.	Brewer
26 to 29.	All shopkeepers.
30.	Bookbinder.
40.	Printer
41.	Watch, clock, scientific instrument maker, jeweller, &c.
42.	Saddler, harness maker.
43.	Butcher.
44.	Miller, cereal food manufacturer
45.	Baker, confectioner.
46.	Hatter.
47.	Tailor.
48.	Shoemaker.
49.	Hairdresser.
50.	Tallow, soap, glue, candle manufacture.
51.	Tanner.
52.	Currier, &c.
53.	Engine, machine, boiler maker, fitter, millwright.
54.	Gunsmith
56.	Lock, key, metallings maker, gasfitter
57.	Blacksmith, striker.
58.	Nail, anchor, chain, and iron and steel manufacture.
59.	Copper, tin, zinc, lead, brass maker, and worker.
60.	Bricklayer, mason, builder.
61.	Carpenter, joiner.
62.	Slater, tiler.
63.	Paperhanger, plasterer, whitewasher
64.	Plumber, painter, glazier.
65.	Cabinet maker, &c.
66.	Sawyer
67.	Wood turner, cooper, &c.
68.	Coach, carriage, railway coach maker, &c.
69.	Wheelwright.
70.	Shipbuilder
71.	Chemical manufacture
72.	Wool, worsted manufacture
73.	Silk, satin, crape, &c., manufacture.
74.	Cotton manufacture.
75.	Lace manufacture
76.	Rope, twine, sailmaker
77.	Textile dyer, bleacher, printer, &c.
78.	Oxygen, fur, felt manufacture.
79.	Hosiery manufacture
80.	Paper manufacture.
81.	Potter, earthenware, &c., manufacture.
82.	Glass manufacture
83.	Coalheaver
91.	Gas works service.
92.	Dockyard, railway labourer, navvy, &c.
93.	Brick, plain tile, terra-cotta maker.
95.	Indiarubber worker, waterproof goods maker.
109.	Broom, brush-maker, hair bristle worker.

Table 3. All Ages (Comparative Mortality Figures).

Data.	*All Causes less Accident, Suicide, and Phthisis.*		*Phthisis.*		*Correlation.*	*Regression.*
	Mean.	*Standard Deviation.*	*Mean.*	*Standard Deviation.*		
	x	x	y	y		
1890-2	885·2	229·8	163·79	74·32	+ 0·5612	$y = 0{\cdot}1815\ x + 76{\cdot}13$
1900-2	682·7	143·41	181·55	61·01	+ 0·5890	$y = 0{\cdot}2506\ x + 10{\cdot}47$
1910-12	617·5	144·33	153·3	54·78	+ 0·6155	$y = 0{\cdot}2337\ x + 8{\cdot}970$
* Dutch data.	5·608	1·510	2·123	0·0746	· 0·4070	$y = 0{\cdot}2056\ x + 0{\cdot}1093$

* The Comparative Mortality Figures for the 3 sets of English data show the numbers of deaths that would have occurred in a standard population which produced 1,000 deaths from All Causes among Males aged 25-65 years in England and Wales in 1900-2 had the specific death rates been applicable to the standard. The Dutch data are death rates per 1,000 in towns of a standard population based on the age distribution of occupied males aged 18-64. (See *Indrages tot de Statistiek van Nederland*, No. 247, p. vi.)

TABLE 4. ALL AGES. Occupations having Phthisis death-rate 25 per cent. above (+) or 25 per cent. below (−) the Expected death-rate.

Ref. No.	Occupation.	1890-2	1900-2.	1910-12.	Dutch.
16.	Bargeman, lighterman	..	−	−	+
20.	Farmer, grazier	..	−	−	...
21.	Farm labourer, farm-servant	..	..	..	...
22.	Gardener, nurseryman	..	−	..	..
23.	Fisherman	..	..	−	..
24.	Maltster	..	−	−	..
39.	Bookbinder	+	+	+	+
40.	Printer	..	+	+	+
41.	Watch, clock-maker	+	..	+	...
42.	Saddler, harness-maker	+	+	..	..
43.	Butcher	..	..	−	..
44.	Miller, cereal food-maker	..	−	−	−
46.	Hatter	+	+	+	..
47.	Tailor	+	+	+	+
48.	Shoemaker	+	+	+	...
49.	Hairdresser	+	+	+	−
50.	Tallow, soap manufacture	..	..	...	..
51.	Tanner	−	..	−	...
52.	Currier, &c.	..	..	+	..
53.	Gunsmith	+	..	+	...
56.	Lock, key, gasfittings-maker	..	+	..	...
65.	Cabinet maker	+	+	+	+
66.	Sawyer	..	..	..	−
67.	Wood-turner, cooper, &c.	..	+	+	+
69.	Wheelwright	..	..	−	..
70.	Shipbuilding	+	..	−	−
71.	Chemical manufacture	..	−	−	..
78.	Carpet, rug manufacture	..	..	..	+
79.	Hosiery manufacture	+	+	+	...
80.	Paper manufacture	−	..	..	...
85.	Potter, earthenware manufacture	..	..	+	..
92.	Platelayer, railway labourer, navvy	..	−	−	..
97.	Brick, plain tile, terra cotta maker	−	−	..	..
102.	Indiarubber worker, waterproofs	..	+	...	...
103.	Brush, &c. brush-maker, hair-bristle worker	..	+	+	..

TABLE 5. AGE GROUPS, 1900–2 (DEATHS PER 1,000 LIVING).

Ages.	*All Causes less Accident, Suicide, and Phthisis.*		*Phthisis.*		*Correlation.*	*Regression.*
	Mean.	*Standard Deviation.*	*Mean.*	*Standard Deviation.*		
	$\bar{x}$	σ_x	$\bar{y}$	σ_y		
20–25	2·244	0·6157	1·611	0·7244	+ 0·3623	$0·4264\,x + 0·6541$
35–45	6·218	1·757	2·817	1·062	+ 0·4880	$0·2950\,x + 1·0090$
55–65	28·94	5·812	2·377	0·8064	+ 0·5088	$0·0706\,x + 0·3306$
35–45 Dutch data	1·104	1·178	1·745	1·042	+ 0·3710	$0·3296\,x + 0·3920$

Table 6. Age-Groups, 1900-2.

Occupations having Phthisis death-rate 25 per cent above (+) or 25 per cent. below (−) the Expected death-rate.

		20-25.	35-45	55-65	35-45 Females.
15.	Carman, carrier	−	.	.	.
16.	Bargeman, lighterman	−	.	.	.
18.	Dock labourer	...	...	...	−
20.	Farmer, grazier	−	−	−	−
21.	Farm labourer, farm servant	−	−	−	...
22.	Gardener, nurseryman	−	−	...	...
23.	Fisherman	−	...	...	...
24.	Maltster	...	−	...	...
25.	Brewer	−	...	...	...
28.	Stationery manufacture	...	...	...	+
39.	**Bookbinder**	+	+	+	+
40.	Printer	+	+	+	+
41.	Watchmaker, jeweller	...	...	+	...
42.	Saddler and harness maker	+	...	...	...
43.	Butcher	−	.	−	...
44.	Miller	−	...	...	−
45.	**Baker and confectioner**	...	...	...	−
46.	**Hatter**	+	+	...	...
47.	Tailor	+	+	...	+
48.	**Shoemaker**	+	+	...	...
49.	Hairdresser	+	+	...	...
51.	**Tanner**	...	−	...	...
52.	**Currier**	+	+	...	...
58.	Gunsmith	−	...	+	...
59.	Lock-maker, gasfitter	−	...	+	...
57.	Blacksmith, striker	−	...	...	...
58.	Nail, anchor, chain-maker	−	...	...	...
60.	Bricklayer, mason	−	...	+	...
61.	Carpenter and joiner	...	...	...	+
62.	Slater and tiler	−	...	−	...
63.	Paperhanger, plasterer	−	+	+	+
64.	Cabinet-maker	...	+	...	+
66.	Sawyer	...	−	...	−
67.	Wood turners and coopers	...	...	...	+
68.	Coach, carriage-maker	−	...	−	...
70.	**Shipbuilding**	...	...	−	−
71.	Chemical manufacture	−	−	−	...
72.	**Wool, worsted manufacture**	+	...	...	...
73.	Silk, gauze, crape manufacture	+	−	+	...
76.	Rope, twine, cord maker	...	...	+	...
77.	Textile dyer, bleacher	...	...	−	...
78.	**Carpet, rug manufacture**	+	...	...	...
79.	Hosiery manufacture	...	...	+	...
82.	Glass manufacture	...	+	...	+
90.	Coalheaver	...	...	−	−
91.	Gas works service	...	−	...	...
92.	Platelayer, navvy	...	−	...	...
97.	Brick and tile maker	−	−	−	−
100.	Indiarubber worker	−	...	...	...
101.	Brush maker, hair-bristle worker	+	+	...	...

TABLE 7. CORRELATIONS. REGRESSION. AGE GROUPS.

All Causes, 1890-2. *Age Group.* 25-35 = *a*.	*All Causes less Accident, Suicide, and Phthisis.* 1900-2. 35-45 = *x*.		*Phthisis*, 1900-2. 35-45 = *y*.
Mean a = 7·701.	*Mean x* = 6·201.		*Mean y* = 2·777.
Standard Deviations:	$\sigma_{y.x\,a}$ = 0·842.	$\sigma_{x\,ay}$ = 0·728.	$\sigma_{a.xy}$ = 0·970.
Correlations:	$r_{yx.a}$ = 0·096.	$r_{ya.x}$ = 0·239.	$r_{xa.y}$ = 0·838.
Regression:	y = 0·106 x + 0·198 a + 0·589.		

Table 8. Leipzig Ortskrankenkasse Experience.

Special Trades employing at least 1,000 Women between the ages 15–35.

Trade	Years of Life at Risk.	All Causes.	In Terms of Average.[1]	Respiratory Diseases.	In Terms of Average.[1]	Accidents	In Terms of Average.[1]	Tubercle Case Rate per 1,000.	In Terms of Average.	In Terms of Corresponding Male Rate.	Heart Diseases Case Rate	In Terms of Average.[1]	Nervous Diseases Case Rate	In Terms of Average.[1]
Domestic general servants	17,040	240·7	58	20·1	51	5·3	36	2·2	33		4·7	74	6·2	49
Cooks	7,067	306·4	71	30·2	81	1·5	50	1·7	26		4·8	76	9·1	72
Waitresses	1,060	295·8	69	21·3	62	0·5	6	3·7	56	70	2·0	31	9·9	79
Washerwomen and ironers	4,341	360·4	84	26·9	72	0·1	67	1·9	29	..	2·6	41	12·4	99
Shop assistants	21,038	304·2	71	27·5	74	0·9	10	2·8	42	30	6·8	107	11·7	93
Office assistants (typists, clerks, &c.	11,204	242·3	54	28·4	76	0·6	7	4·1	56	19	4·6	72	13·8	110
Tailoresses and seamstresses general	19,852	360·9	84	40·1	109	2·5	28	6·5	98	83	6·3	99	12·6	100
Tailoresses and seamstresses private	14,332	292·3	75	30·1	97	2·2	23	6·1	92	61	7·0	110	10·9	87
Millinery makers	6,709	320·6	74	26·8	72	1·3	14	7·1	107	..	6·2	98	10·9	87
Bookbinders	20,742	476·7	113	55·4	148	13·0	143	9·5	143	93	7·5	118	16·3	130
Other manufacturing book trade hands	13,191	462·2	107	26·9	72	17·7	195	8·0	120	90	6·8	107	12·9	103
Auxiliary book trade hands	6,634	484·3	113	29·8	80	15·2	167	7·5	113	51	7·5	118	13·4	107
Coloured and luxus paper factories	7,121	524·7	122	26·5	71	14·1	144	5·2	78	116	6·5	102	13·2	105
Musical instrument factories	2,215	436·3	101	32·5	84	11·2	123	6·5	98	66	7·3	115	9·9	79
Metal factories	4,266	563·6	131	26·3	70	41·2	446	10·1	152	131	4·3	68	17·3	137
Mineral water, vinegar, jam, &c., factories	1,204	420·7	123	25·2	65	14·7	162	8·4	127	102	12·5	197	10·3	82
Weavers	5,114	529·4	123	26·5	71	14·5	149	8·4	127	..	6·4	101	11·6	92
Embroiderers	5,223	372·7	87	33·4	89	1·4	15	12·8	194	..	6·2	98	13·6	108
Boot and shoe factories	1,731	390·9	91	43·3	116	6·5	72	5·8	87	57	5·8	91	6·9	55
Furriers	1,466	548·6	124	88·9	238	7·8	86	6·4	96	81	5·7	90	10·0	79
Toy factories	1,888	556·7	126	53·5	142	9·0	99	8·5	128	91	9·5	150	13·2	105
Measuring instrument factories	2,073	518·6	120	56·0	150	17·4	191	6·3	95	34	4·3	68	7·7	61
Rubber factories	2,697	666·1	141	59·6	159	6·2	68	6·7	101	61	7·2	113	32·4	258
Tobacco and cigar factories	1,292	451·2	105	57·3	153	4·6	51	14·7	221	84	3·6	61	11·6	92
Type foundries	1,270	466·9	108	39·4	105	5·5	61	6·3	95	66	7·9	124	13·4	107
Photographic processes	2,078	376·1	83	44·8	120	1·0	11	4·8	72	126	9·6	151	12·5	99
Wool combers and spinners	16,119	508·1	139	25·4	68	21·5	237	7·6	114	107	7·0	120	16·1	128

[1] Unweighted average of the 27 groups.

Table 9. Bavarian Phthisis Mortality, 1908.

(Koelsch in Mosse and Tugendreich, I. 182.

Occupation.	Age Classes. 15-19.	20-29.	30-39	40-49.	50-59.	60-69.	All Ages.	Population.	Per 1,000.
Women.									
Peasants	126	290	394	219	167	134	1,240	867,902	1·43
Flower-makers	...	3	3	...	...	...	6	901	6·66
Brushmakers	1	5	1	...	...	1	7	2,904	2·41
Deaconesses	...	1	4	1	...	...	7	921	7·60
Waitresses	2	12	3	...	1	...	18	11,246	1·60
Nuns	2	41	13	9	2	3	100	13,564	7·37
Teachers	3	10	3	...	...	6	18	11,632	1·55
Domestic servants	72	179	72	27	19	10	379	27,350	13·86
Seamstresses	10	81	39	9	9	5	163	25,157	6·48
Day workers	1	10	18	25	13	13	80	2,292	34·90
Sales women	11	22	5	3	...	...	41	16,892	2·43
Washerwomen, ironers	1	8	2	6	3	1	21	9,244	2·27
Tobacco workers	...	7	2	...	...	...	9	6,508	1·38
Other occupations	539	1,511	1,390	808	590	170	5,308	1,305,584	4·07

TABLE 10. SCHULLER AND BURCKHARDT'S SWISS (1880-4) EXPERIENCE.* DISTRIBUTION OF CAUSES OF SICKNESS PER 100 CASES.

Causes	Cotton			Embroiderers	Silk Weavers	All Textile Workers
	Spinners	Weavers	Workers			
Of the digestive organs	27·1	30·0	28·9	9·0	20·1	30·7
Respiratory	18·9	28·3	17·1	15·8	18·8	18·1
Of circulation	1·2	1·5	0·4	0·5	1·3	1·3
Of locomotion	9·5	6·2	6·5	6·7	8·2	7·1
Of the nervous system	2·2	2·1	1·7	0·9	0·7	1·9
Of the skin	6·2	4·1	10·6	12·5	4·5	8·7
Of the eyes	2·7	3·6	2·9	5·1	2·8	4·3
Urinary and sexual	3·2	5·6	0·3	3·1	4·6	4·8
Childbirth	3·9	3·1	2·5	4·3	7·1	4·3
Constitutional	15·6	13·1	19·2	—	17·1	14·7
Injuries	5·3	7·9	4·8	6·8	9·2	9·7
Miscellaneous	4·2	3·5	2·5	2·9	3·4	3·5

* See Prinzing, *Handbuch d. medic. Statistik*, p. 139.

TABLE 11. FRANKFURT, 1896 (INCIDENCE PER 100 FEMALE MEMBERS). (PRINZING.)

Diseases.	Servants.		Waitresses.		Shop Assistants.		Seamstresses.		All.	
	Able to work.	*Unable to work.*	*Able to work.*	*Unable to work.*	*Able to work.*	*Unable to work.*	*Able to work.*	*Unable to work.*	*Able to work.*	*Unable to work.*
Infectious	1·8	3·3	1·5	3·0	1·5	3·0	1·0	4·4	1·6	4·0
Tuberculosis	2·2	1·9	3·2	2·0	5·1	3·7	4·1	3·2	3·0	3·0
Anæmia and Chlorosis	0·6	1·9	9·2	1·7	23·9	6·2	17·1	0·2	14·6	5·0
Syphilis	0·3	0·5		0·2	0·1		0·5	0·3	0·4	0·2
Nervous	2·3	0·3	2·3	0·3	7·3	1·7	4·3	1·8	4·5	1·2
Of the digestive organs	8·3	4·1	12·6	1·3	10·2	5·5	9·8	6·7	9·5	6·1
Circulatory	0·9	0·5	2·3	1·5	2·0	0·7	0·0	0·8	1·2	0·8
Sexual	2·1	1·0	3·7	2·2	3·7	1·4	2·6	1·0	3·0	1·6
Respiratory	6·0	1·3	5·5	4·4	10·7	5·8	8·2	7·0	7·8	5·8
Locomotion	4·7	4·1	7·9	2·5	5·0	2·5	4·7	1·0	4·9	3·9
Skin	6·1	4·1	7·9	1·1	11·3	3·0	6·1	2·2	7·5	3·4
Eyes	3·9	0·6	2·0	0·5	8·0	0·0	0·5	0·6	5·8	0·6
Accidents	6·2	2·3	2·3	2·5	2·8	1·0	1·6	1·2	2·4	1·9
Other diseases	7·0	1·7	8·0	1·5	18·7	1·9	12·7	1·4	12·8	1·9
All diseases	58·6	29·6	65·1	30·3	119·3	37·9	80·8	40·8	79·0	39·4

TABLE 12. AUSTRIAN OCCUPATIONAL MORTALITY. 1891–5. PER 1,000 LIVING.

(Cited from Mosse and Tugendreich, p. 200.)

	15–20.	20–30.	30–40	40–50.	50–60.	Standard
All male operatives	5·2	6·6	9·0	14·2	23·1	100
All female operatives	8·1	9·2	10·0	12·4	17·1	109
Tailors	5·9	5·3	7·8	12·5	17·1	86
Glove-makers	8·9	10·1	8·2	15·2	31·7	132
Textile workers	9·8	11·3	10·9	12·2	16·4	121
Tobacco workers	11·0	13·3	12·7	11·4	15·5	133
Brick and cement workers	9·7	6·4	6·5	10·2	10·6	84
Clay and porcelain workers	7·7	10·3	10·8	15·7	24·2	126
Wood workers	8·2	8·6	11·2	14·7	32·4	127
Clothing factories	8·6	11·8	10·4	6·3	11·3	105

TABLE 13. CORRELATIONS OF THE TUBERCULOSIS RATES WITH OTHER RATES.

Leipzig. Women. Ages 15–34. Case Rates.

Tubercle with all causes less tubercle and cardiac diseases	$r = 0{\cdot}491 \pm 0{\cdot}10$
.. .. cardiac diseases	$r = 0{\cdot}214 \pm 0{\cdot}13$
.. .. nervous diseases	$r = 0{\cdot}231 \pm 0{\cdot}12$

English. Men. Ages 15–34. Death Rates.

Tubercle with cardiac diseases 48 occupational groups	$r = 0{\cdot}27 \pm 0{\cdot}08$

TABLE 14. PERCENTAGE OF DEATHS FROM PHTHISIS UPON NOTIFIED CASES.

Locality.	*Administrative Unit.*	1913.	1914.	1915.	1916.
St. Helens	Co. Bo.	...	...	...	67·2
Lancashire	C. C.	53·4	54·0	56·2	62·7
Carlisle	Co. Bo.	..	38·7	57·6	...
Wolverhampton	Co. Bo.	..	..	60·8	..
Huddersfield	Co. Bo.	...	47·5	65·0	...
Birkenhead	Co. Bo.	..	45·0	...	52·1
Halifax	Co. Bo.	.	66·1	79·6	...
Northamptonshire	Urban and Rural	.	51·4	64·1	...
Northumberland	C. C.	...	67·0	...	...
Chelsea	Met. Bo.	...	53·5	73·9	47·9
Berkshire	C. C.	..	44·6	41·4	...
Crewe	M. B.	..	54·0	..	...
Darlington	Co. Bo.	...	45·1	..	.
Hull	Co. Bo.	..	60·2	...	..
Holborn	Met. Bo.	...	80·0	45·1	...
St. Marylebone	Met. Bo.	...	...	40·9	...
Lincolnshire—parts of Holland	C. C.		58·2	...	...
Lincolnshire—parts of Lindsay	C. C.	.	71·5	...	...
Poplar	Met. Bo.	.	...	52·8	...
Essex	C. C.		40·6	..	...
Leyton	U. D.		38·5		...
Brighton	Co. Bo	..	50·9	...	...
Hove	M. B.	..	49·4	62·1	..
Bootle	Co. Bo.	...	35·0	45·7	..
Great Yarmouth	Co. Bo.	..		108·7	.
Preston, Lancs.	Co. Bo.	..	37·5	38·3	37·4
Colchester	M. B.	34·3	49·5	78·8	..
Shropshire	C. C.	..	79·7		...
Nottingham	Co. Bo.	15·1	41·2		...

TABLE 15. CORRELATIONS BETWEEN DEATH-RATES FROM PULMONARY TUBERCULOSIS AND DEATH-RATES FROM ALL OTHER CAUSES AMONG WOMEN AGED 15–45 IN THE YEAR 1911.

Metropolitan and County Boroughs	$r = 0.202 \pm 0.06$
Urban districts	$r = 0.103 \pm 0.07$
Rural districts	$r = 0.348 \pm 0.04$
33 large industrial towns	$r = 0.320 \pm 0.0$

TABLE 16. PROPORTIONATE MORTALITY AND DEATH-RATE (PHTHISIS). EXPERIENCE 1891–1900. 168 ENGLISH REGISTRATION DISTRICTS. (SEE TABLE 17 *b*.)

Proportionate Mortality.	Number of Observations.	Observed Mean Rate of Mortality.	Mean Rate of Mortality calculated from Regression Equation.
0·17	7	1·47	1·66
0·22	21	2·02	1·98
0·27	40	2·40	2·30
0·32	48	2·58	2·62
0·37	20	2·91	2·94
0·42	6	2·50	3·26
0·47	8	4·13	3·58
0·52	2	4·01	3·90
0·57	3	4·42	4·22
0·62	2	4·51	4·54
0·67	1	5·20	4·87
0·72	..	..	5·19
0·77	..	..	5·51
0·82	1	4·70	5·83

Goodness of Fit P = 0·27.
See Pearson, *Biometrika*, 1916, 11, 250.

TABLE 17 *a*.

OCCUPATIONS. AGES 35–45. MORTALITY 1900–2. R. G.

Proportionate Mortality (Ratio of Deaths from Phthisis to Deaths from all other causes) and Phthisis Death-rate.

Correlation.	Regression Equation.
0·754 ± 0·04	$y = 0{\cdot}0175 + 0{\cdot}6309\,x$

y is the Death-rate, *x* is Proportionate Mortality.

TABLE 17 *b*.

168 REGISTRATION DISTRICTS, EACH OF MEAN POPULATION GREATER THAN 50,000. R. G. DECENNIAL SUPPLEMENT, 1890–1900.

Proportionate Mortality. (1,000 Deaths = 1,000 *y*.)

Mean.	Standard Deviation.	Mean.	Standard Deviation.
0·3013	0·097	2·948	0·992

Correlation and Correlation-ratio, 0·929 ± 0·03.
Correlation Ratio = 0·863.
Death-rate on Proportionate Mortality.
Regression Equation $y = 0{\cdot}410\,x + 0{\cdot}573$.

TABLE 18. SHOWING *INCREASED* RATES OF DEATHS FROM TUBERCULOSIS AND ALL OTHER CAUSES, 1913–16.

Women, ages 15–45.

Metropolitan and County Boroughs.	1916.	1915.	1914.	1913.
Battersea	·50	·65	·43	·32
Bermondsey	·66	·54	·39	·41
Bethnal Green	·51	·43	·60	·45
Camberwell	·70	·50	·48	·39
Deptford	·58	·61	·60	·46
Finsbury	·67	·48	·27	·57
Fulham	·64	·48	·43	·41
Greenwich	·46	·54	·34	·34
Hackney	·60	·49	·46	·51
Hampstead	·40	·14	·37	·22
Islington	·50	·46	·35	·39
Kensington	·48	·38	·42	·34
Lambeth	·57	·41	·51	·46
Lewisham	·44	·47	·34	·27
Poplar	·51	·53	·34	·43
St. Pancras	·49	·43	·44	·28
Shoreditch	·47	·61	·54	·33
Southwark	·56	·36	·38	·49
Stepney	·52	·48	·38	·30
Stoke Newington	·30	·28	·46	·32
Wandsworth	·40	·55	·45	·31
Westminster	·33	·31	·29	·27
Bath	·50	·40	·31	·27
Birkenhead	·43	·32	·32	·31
Birmingham	·40	·39	·30	·35
Blackburn	·34	·20	·23	·22
Blackpool	·32	·32	·41	·19
Bolton	·35	·36	·39	·24
Bootle	·75	·48	·30	·37
Brighton	·51	·54	·54	·38
Burnley	·35	·25	·20	·28
Burton-on-Trent	·30	·93	·95	·33
Bury	·38	·62	·31	·37
Canterbury	·54	·17	·47	·32
Coventry	·49	·53	·46	·48
Croydon	·64	·45	·41	·42
Derby	·50	·36	·38	·48
Dewsbury	·31	·23	·31	·23
Exeter	·72	·79	·40	·40
Gateshead	·43	·10	·42	37
Gloucester	·62	·59	·50	·17
Grimsby	56	41	·29	47
Halifax	42	38	40	·28
Hastings	·60	81	58	·27
Huddersfield	34	·28	·18	·25
Hull	·57	83	·37	41
Ipswich	48	·73	58	·33
Leeds	·55	·43	43	48
Leicester	50	52	·54	·62
Liverpool	81	·40	48	·33
Manchester	52	·48	42	·42
Middlesbrough	42	·44	·29	·37
Newcastle	40	35	·38	·40
Newport (Mon.)	·41	·28	45	·37
Norwich	·60	61	62	·37

TABLE 18 *(continued).*

Municipal Boroughs, &c.	1916.	1915.	1914	1913.
Nottingham	·48	·55	54	59
St. Helens	·40	32	·28	43
Salford	·44	54	·39	37
Sheffield	·32	·33	·30	27
Smethwick	·54	36	35	50
Southampton	61	·51	51	55
Southend-on-Sea	·04	·00	·37	
Stoke-on-Trent	·49	·37	35	38
Cumberland	·52	·44	42	39
Wallasey	·27	·31	·39	24
Walsall	·52	·50	34	43
Warrington	·74	48	50	35
West Bromwich	·43	43	46	26
Westham	·50	·44	43	44
Wolverhampton	·51	40	29	50
York	42	52	38	36
Cardiff	62	47	·49	52
Merthyr Tydfil	·54	42	·47	46
Swansea	·60	46	·65	36

TABLE 18*a*. *Administrative Counties.*

Urban and Rural Districts.	1916.	1915.	1914	1913.
Bedford U.	50	·28	46	46
Berks U.	·46	22	·35	·45
Berks R.	·44	38	37	·37
Bucks. R.	·46	27	36	46
Cambridge U.	60	·27	54	35
Cambridge R.	·71	·31	57	38
Cheshire U.	·33	·37	31	32
Cornwall U.	·57	53	·57	·55
Cornwall R.	·55	10	49	49
Derby U.	41	37	13	31
Derby R.	·28	37	25	26
Devon U.	·67	38	46	36
Devon R.	·46	56	43	45
Dorset U.	·51	44	·43	39
Dorset R.	·44	31	28	40
Durham U.	·40	36	34	35
Durham R.	42	41	31	30
Essex R.	·32	43	37	30
Hereford U.	·67	43	57	50
Hereford R.	·43	67	52	42
Hertford U.	38	60	42	35
Huntingdon R.	48	58	20	47
Isle of Ely U.	·73	38	·40	62
Isle of Ely R.	60	·23	33	26
Kent U.	46	42	·37	·37
Lancaster U.	·36	37	32	41
Lancaster R.	38	28	36	27
Lincoln (Holland) U.	59	87	28	30
Lincoln, Kesteven, U.	31	20	23	28
Lincoln, Kesteven, R.	60	·25	·30	48
Lincoln, Lindsey U.	53	30	37	40
Lincoln, Lindsey R.	62	45	40	51
Middlesex U.	·47	30	48	40
Monmouth U.	36	28	26	24
Monmouth R.	74	·59	50	14
Norfolk R.	62	69	42	47
Norfolk U.	61	53	·47	49
Northampton U.	57	46	85	59
Northumberland R.	48	56	41	33

TABLE 18*a* (*continued*).

Urban and Rural Districts.	1916.	1915.	1914.	1913.
Nottinghamshire U.	·45	·30	·40	·31
Oxfordshire R.	·38	·47	·41	·26
Peterborough U.	·70	·24	·52	·44
Shropshire U.	·48	·35	·40	·31
Shropshire R.	·43	·42	·32	·29
Somerset U.	·43	·71	·53	·33
East Suffolk U.	·34	·31	·40	·25
East Suffolk R.	·41	·62	·42	·37
West Suffolk U.	·56	·67	·50	·55
West Suffolk R.	·74	·54	·29	·54
Surrey U.	·40	·38	·33	·32
Surrey R.	·51	·39	·37	·27
West Sussex U.	·50	·49	·53	·40
East Sussex R.	·86	·39	·55	·53
East Sussex U.	·67	·35	·24	·50
Warwickshire U.	·40	·41	·40	·16
Warwickshire R.	·38	·37	·40	·28
Westmorland R.	·30	·25	·32	·24
Wiltshire R.	·36	·48	·24	·28
Worcestershire R.	·40	·38	·55	·36
Yorks., E. Riding U.	·51	·37	·56	·24
Yorks., E. Riding R.	·55	·34	·48	·46
Yorks., N. Riding U.	·46	·27	·33	·44
Yorks., N. Riding R.	·30	·34	·41	·24
Yorks., W. Riding U.	·31	·27	·32	·30
Anglesey R.	·70	·70	·46	·63
Brecknock R.	·78	·29	·33	·76
Carmarthen R.	·60	·44	·66	·56
Carnarvon U.	·60	·32	·49	·59
Carnarvon R.	·86	·68	·60	·39
Denbigh U.	·56	·38	·56	·37
Denbigh R.	·43	·31	·46	·21
Flint U.	·58	·32	·26	·46
Glamorgan U.	·45	·34	·33	·41
Glamorgan R.	·47	·44	·45	·33
Merioneth U.	·81	·20	·25	·50
Merioneth R.	·79	·67	·52	·36
Montgomery R.	·58	·53	·75	·48
Pembroke U.	·70	·42	·47	·39
Pembroke R.	·57	·43	·68	·48
Radnorshire U.	·63	·14	·33	...
Radnorshire R.	·54	·67	·38	·50

TABLE 19. SHOWING RATIO OF DEATH FROM TUBERCULOSIS AND ALL OTHER CAUSES *NOT INCREASED*, 1913–16.

Women, ages 15–45.

County Boroughs	1916.	1915.	1914.	1913.
Barnsley	·29	·27	·49	·29
Barrow in Furness	·29	·35	·40	·38
Bournemouth	·62	·84	·63	·89
Bradford	·32	·34	·52	·38
Bristol	·51	·54	·41	·51
Chester	·45	·38	·32	·48
Chelsea	·19	·39	·28	·20
Dudley	·37	·42	·38	·52
Eastbourne	·39	·31	·50	·44
Great Yarmouth	·75	·70	·70	·89
Hammersmith	·52	·40	·37	·54
Holborn	·31	·27	·53	·45

TABLE 19 (*continued*).

Lincoln	·46	·43	49	49
Northampton	48	58	52	49
Oldham	52	48	48	52
Oxford	50	44	49	50
Paddington	38	41	43	46
Plymouth	49	·44	48	55
Portsmouth	46	35	47	47
Preston	28	35	·28	30
Reading	47	52	53	49
Rochdale	35	·28	49	49
Rotherham	39	·37	48	49
St. Marylebone	25	·28	26	29
Sandhurst	33	25	32	35
South Shields	41	31	45	43
Stockport	42	·48	51	50
Tynemouth	37	32	·48	45
West Hartlepool	49	·37	48	50
Wigan	34	47	29	35
Woolwich	34	39	44	49
Worcester	51	·45	49	52

Averages for counties. *Other rural districts.*				
Bedford R.	61	·59	40	52
Bucks. U.	53	55	59	44
Chester R.	20	22	22	·34
Cumberland U.	·43	·35	44	50
Cumberland R.	·30	35	43	47
Essex U.	40	·38	38	41
Gloucester R.	39	·44	56	42
Gloucester U.	·45	·48	47	62
Hertford R.	58	39	56	45
Huntingdon U.	53	·33	19	53
Isle of Wight R.	22	29	33	44
Isle of Wight U.	28	20	33	41
Kent R.	·46	47	48	47
Leicester R.	51	·45	55	61
Leicester U.	·33	·47	50	53
Lincoln R.	45	45	34	73
Middlesex R.	32	26	27	53
Northampton R.	54	52	48	60
Northampton U.	62	56	48	62
Nottinghamshire R.	35	31	36	39
Oxford U.	65	41	49	63
Peterborough R.	40	45	60	50
Rutland R.	11	—	17	21
Rutland U.			...	50
Somerset R.	·40	51	39	43
Southampton R.	·39	44	50	40
Southampton U.	31	35	·35	38
Stafford R.	32	43	38	39
Stafford U.	40	34	38	43
Sussex W. R.	46	38	49	·55
Westmorland U.	29	·35	40	33
West Yorkshire R.	34	33	40	40
Wiltshire	33	33	33	33
Worcester U.	43	32	37	44
Anglesey U.	48	40	39	46
Brecknock U.	40	53	45	46
Cardigan U.	61	60	25	67
Cardigan R.	69	80	59	71
Carmarthen U.	·43	69	46	53
Flint R.	35	26	34	44
Montgomery U.	58	64	33	54

Table 20 *a*. Industrial Towns and Boroughs.

Rates Increased.		*Rates not Increased.*
Bermondsey	Huddersfield	Barrow-in-Furness
Bethnal Green	Hull	Bradford
Deptford	Ipswich	Chester
Finsbury	Leeds	Dudley
Fulham	Leicester	Northampton
Greenwich	Liverpool	Oldham
Hackney	Manchester	Preston
Lambeth	Middlesbrough	Reading
Poplar	Newcastle	Rochdale
St. Pancras	Newport Mon.	Rotherham
Shoreditch	Norwich	South Shields
Southwark	Nottingham	Stockport
Stepney	St. Helens	Tynemouth
Birkenhead	Salford	West Hartlepool
Birmingham	Sheffield	Wigan
Blackburn	Smethwick	Woolwich
Bolton	Stoke-on-Trent	
Bootle	Sunderland	
Burnley	Wallasey	
Burton-on Trent	Walsall	
Bury	Warrington	
Coventry	West Bromwich	
Croydon	West Ham	
Derby	Wolverhampton	
Dewsbury	Cardiff	
Gateshead	Merthyr Tydfil	
Halifax	Swansea	

Table 20 *b*. Non-Industrial Towns and Boroughs.

Rates Increased.	*Rates not Increased.*
Battersea	Chelsea
Camberwell	Hammersmith
Hampstead	Holborn
Islington	Paddington
Kensington	St. Marylebone
Lewisham	Bournemouth
Stoke Newington	Eastbourne
Wandsworth	Great Yarmouth
Westminster	Lincoln
Bath	Oxford
Blackpool	Portsmouth
Brighton	Plymouth
Canterbury	Southport
Exeter	Worcester
Gloucester	
Grimsby	
Southampton	
Southend-on-Sea	
Hastings	
York	

Part V. The Factory Conditions Observed in Birmingham in 1917.

In order to get some idea of the present distribution of Pulmonary Tuberculosis in an industrial population, so far as it is possible to do so by the study and analysis of a small sample, an investigation was carried out at Birmingham in November–December 1917, the data made use of and the method adopted being the following:

The Special Investigation Committee upon the Incidence of Phthisis in relation to Occupations appointed by the Medical Research Committee of the National Health Insurance Commission had already available a considerable body of information on this matter in the form of a card-index referring to certain large manufacturing towns, Manchester, Sheffield, Birmingham, Belfast, &c.. A request had been made in each instance to the Medical Officer of Health, Chief Tuberculosis Officer or other responsible authority for a return both current and retrospective of all persons notified for Tuberculosis who were also engaged in any industry or occupation.

Among the places mentioned Birmingham was chosen as being possibly that best suited for the inquiry projected, since it fairly represents in all essential ways average conditions of life of the working folk in a large industrial centre, and also for the fact that Ministerial control gave a wide portal of entry into workshops of all types and sizes, such as could not at the present time have been obtained by any other means.

A preliminary scrutiny of the cards which had accumulated for Birmingham during the period of six years since voluntary and later compulsory notification of Tuberculosis began (viz. December 1911–November 1917) showed them to include the names of 972 persons referable to firms under the control of the Ministry of Munitions. A second sorting was by industries, which being found to be numerous as well as very varied in character, necessitated some further limitation.

Birmingham's leading industry, the non-ferrous metal trade, was therefore selected, since it draws by far the greater part of the working population, at all ages, into its net, and such avocations were chosen as could be embraced by this general designation and again, since it would have been impossible to visit every one of the 202 controlled establishments named on the cards (although large, medium sized, and small works were included for examination), those containing the smallest numbers of hands, and in which usually not more than a single case of Tuberculosis had occurred during the whole-time period involved, were rejected.

Forty works were visited and since particular trades tend to settle in particular neighbourhoods, a principle adopted was to include at least one establishment in each important trade area or district.

A thorough inspection in detail of the whole of the premises connected with each works or firm visited was in all cases made; a full explanation of the objects of the inquiry was found to be an

effective means of securing the willing consent and co-operation of the manager, or other representative, and whenever possible the assistance of the Welfare Supervisor was obtained in going round, on account of her wide personal acquaintance with the employees. Large numbers of people occupied on all sorts of work were seen. The general structure, aspect, means of heating and ventilation the lighting of premises and of the work, numbers of employees, their position while at work and relative to one another, the machines, tools and materials, hours of work and of rest, trade habits and factory hygiene were gone into, as well as all other matters which have been thought to influence or affect in any way the incidence or prevalence of Tuberculosis in workshops.

After inspecting the factories a series of visits was made to the homes of notified persons.

The Tuberculosis Department divides up the whole city into ten administrative areas, each of which has its own Tuberculosis Visitor. By the courtesy of the Medical Officer of Health I was enabled to obtain the assistance of the latter in arranging itineraries so as to traverse the whole district and so to distribute my visits as to take in streets and houses in each area, and in this way to get a fairly comprehensive view of working-class housing conditions in Birmingham generally and more particularly of those of the persons under review.

In all the works inspected, as many of the notified persons as could be identified were briefly questioned about themselves. In 162 cases in addition to this, it was found possible to verify or to correct, as well as to amplify the information returned on their cards, and so to render the latter sufficiently exact for tabulation.

Of these 162 persons 105 were males and 57 females. Table I gives their sex and age distribution, the latter being put into the most usual quinquennial and decennial periods.

TABLE I.

Ages of cases of Notification.	Males.	Females.	Total.	Per cent.
15–20 inclusive	14	16	15	9·3
21–25 ,,	18	13·1	14	8·6
26–35 ,,	32	19·7	18	11·1
36–45 ,,	26	16·6	19	11·7
46–55 ,,	4	6·5		
56 and upwards		0·6		..
Ages not known, or not stated	3	1·8		

* 1. A cured case. Now in Army. Mother and home seen.
2. Father of a case on cards, working at same firm as daughter. Not visited, but not indexed.
3. Husband of a case on cards. Invalided out of Army. Seen while calling on wife. Not indexed.

Table II is a list giving the original trade designations of the firms visited—many of which have more than one works in Birmingham.

Table II.

[illegible]	1 firm
[illegible]	1 ,,
[illegible]	1 ,,
Brass and copper founders	1 ,,
[illegible]	1 ,,
[illegible]	1 ,,
[illegible]	1 ,,
[illegible]	2 ,,
[illegible]	2 ,,
[illegible]	2 ,,
[illegible]	2 ,,
[illegible]	2 ,,
[illegible]	3 ,,
[illegible]	3 ,,
[illegible]	4 ,,
[illegible]	4 ,,
[illegible]	5 ,,
[illegible]	5 ,,
[illegible]	6 ,,

Table III gives the distribution by original occupations i. e. the kind of work engaged in by each person at the date of notification.

The majority of these persons being still at work many of them are now actually employed on munitions of one kind or another. Obviously, all the firms inspected, being 'Controlled Establishments', are doing war work—but since the term 'Munitions of War' includes, in addition to shells, cartridges, fuses, aeroplanes, &c., everything required by or tolerable in any way to an army in the field, it follows that many of the goods originally produced continue to be required and are still being made in large quantities. Also that where, as in many cases, by expansion or extension of premises the manufacture of articles of a different kind has also been undertaken by a firm the aim has usually been to choose that for which the nature of the material used, the machinery already installed, and the skill of the workers employed therein can be most readily adapted. Hence, those who were formerly pen makers, will now be found engaged on such things as cartridge clips for lorries are worked out of thin sheet metal; screw makers will be making rivets and bolts for aeroplanes; tin plate workers mess-tins; silversmiths friction tubes (which contain an intricate mechanism requiring a nice adjustment) and so on. Thus there is a very close correlation between much of the former work and that now being done by many munitionists while in not a few cases it remains actually the same, though doubtless it is being done at a much greater speed.

Hence, while notifications in some instances date back to pre-war days, work done then and now may often be strictly comparable, since neither in kind of material used, nor in size of work, nor in tools, machinery, position while working, &c, is there any [illegible] difference.

Table III. Occupations. (161 Cases.)

Nature of occupation.	*No. of Cases*
Machinists	27
Fitters (6) and drillers (3)	21
Wire-rope and rope-makers and wire drawers . . .	13
Metal turners, and working lathes and capstans . .	8
Oil-rifles and Lewis gun, and gun-fitchers	8
Polishers	7
Tool-makers	9
Fuse-makers (4) and coin-setters (5)	9
Casters and annealers (5), rollers (2)	7
Fitters (6) and smiths (3)	9
Motor-engine and crane-drivers (3), labourers out-door (6) .	9
Pen processes (2), aluminium welders (2), sand-blasters (2) .	6
In warehouse and packers	7
Clerks, typists, and book-keepers	4

Miscellaneous—one of each.

F. Razor-grinder, chain riveter, armature-winder, 'toster', cook, setter-in 5

M. Electrician, water-tester, joiner, assembler, die-lapper, mechanic, lamp-maker, cycle work, wood-turner, printer, boiler-tube beater

The above figures do not of course throw light upon the prevalence of phthisis among the occupations enumerated because although we know the total populations of the factories, we do not know the occupational distribution within each factory. Such information is naturally unobtainable since the proportion engaged upon each type of work depends upon such variables as contracts in hand, materials obtainable, &c.

The whole of the works visited may for description be conveniently placed, and indeed they fall naturally into two categories or types, *A* and *B*.

A. Large, modern, well-constructed and properly equipped establishments which, according to accepted views conform in a high degree to nearly all such conditions as constitute for the workers a healthy factory environment.

B. Those others of an almost directly opposite type in which hygienic measures, if indeed ever seriously considered at all are as antiquated as is their construction, and to which the term haphazard most fittingly applies.

Type A.

Usually these are very large buildings of recent date several built since the war but seldom older than ten to fifteen years, the skeleton is either of steel or ferro-concrete, &c., or, where rather older, of brick or stone but in either case filled in with a large proportion of glass, the newest having the appearance of huge glass boxes. The

disadvantages of glass for walls lie in two of its physical properties—its imperviousness to air and its diathermancy—so that by its use for this purpose one means of ventilation is lacking which bricks and all other pervious materials possess, namely, that slow but continuously acting interchange between the outer pure and usually cooler and the inner contaminated and usually warmer air; and also that internally such glass-walled and glass-roofed enclosures will be much less equable in temperature than buildings walled and roofed with ordinary and opaque materials, tending to be too hot in summer and too cold in winter. Standing as they generally do on ample ground space, free access of sunlight, daylight, and air reaches them and overshadowing by other buildings is practically impossible. A good orientation can also be secured. Several had roof-lights facing north, but employees usually find these unduly cold in winter, and special heating is necessary to remedy this.

The great disadvantage of north lighting as regards Tuberculosis is that during all the darkest and coldest days of our long winter places so situated will receive a minimum of sunlight and daylight, whereas from all that is known of the lethal effects of sunlight on the Tubercle Bacillus the aim should be to secure the maximum, more particularly at a time of year when consumptives and others are coughing most and the risk of massive infection is greatest.

These works are always provided with means for heating—either hot-air, hot-water, or steam pipes being fixed at various levels or radiators installed. The exception is in some ground floor shops when, for example these are very lofty, to take the biggest work and machines, and have also usually wide doors and other openings; heating would in such cases be practically useless and is not often attempted. Shops of this description are generally very cold in winter, and there is much complaint from workers in them—improvised fires in pails are frequently seen.

Ventilation also has always received consideration by the designers and various well-known systems of ventilation were observed. Also electric fans were often seen in use to meet special cases, but as so often happens, owing to wrong levels being chosen and real adjustment of the direction of the air stream at these levels, for purposes of effective ventilation they were in many cases quite useless.

Apart from special systems of ventilation, however, in all works in category A apportionment of windows is very liberal and all measures and apparatus for their proper opening and adjustment are usually in good order, so that in the great majority of instances effective "natural ventilation" by this means should be obtainable under all ordinary circumstances.

Unfortunately, however, and this applies also very largely to heating, while installations and other means to secure these two ends have been provided—often at great cost—their regulation is in most cases entirely fortuitous and what is nobody's business very soon becomes the business of one or more of the workers themselves and it will usually be these most unsuitable of all to perform these

functions. Hence it frequently happens that in one shop an old bronchitic male and in another some weak, anaemic girl (both with an equal horror of fresh invigorating air—'a dislike of draughts' they phrase it) is allowed to dominate the ventilation and heating arrangements for a hundred or more healthy persons.

In all places where large numbers of workers are employed for many hours on such continuous tasks as are here seen the air temperature tends gradually to rise as the hours pass; naturally this requires regulation, and it should be the prescribed duty of some responsible person to watch the thermometer and to attend to this matter.

Many shops were seen towards the end of work time. Far more often than not the temperature of them had risen too high for comfort, health, and efficient working, and it is no uncommon thing to see hundreds of girls trooping out of workrooms into the cold night air, and all with flushed and perspiring faces.

With due attention to window and other ventilation this overheating need scarcely ever occur—but as a matter of actual observation in these and in all the shops visited, windows are scarcely ever made sufficient use of. Many records were made both of factory and house windows, but are too long for quotation—a single one will suffice. In one of the largest and possibly the best factory in Birmingham, on a fine, bright, sunny, and windless day, there were open in one half of an immense shop (made up of 900 similar lights 24″ × 18″ each) only eight (8) out of a possible forty-five (45) which were made to open—and in the other precisely similar half, not a single one! It is no uncommon thing here to pass factory after factory without seeing a single window open.

The general lighting in all *A* factories is extremely good. A certain amount of obscuring of the glass is necessary to temper the sunlight in summer; also dust and dirt accumulate to some extent on the outside, but on all fine days they are flooded in every corner with sunlight and daylight. Lighting of the work itself is also invariably good and can therefore be dismissed at once.[1]

The standard of cleanliness in *A* shops is usually of the highest. The only dirt generated is metal swarf and dust, both of which being valuable are quickly collected and sent away, and as most of the machine work is 'wet work' very little dust can possibly be inhaled. The very nature of much of the work and of the machines makes cleanliness a necessity. In the polishing and filing shops more dust, and that of a more objectionable character, is generated, and being both finer and lighter than metal dust could more easily be inhaled; but adequate exhausts are provided, and, except immediately around a polisher, there is astonishingly little accumulation of dust by the end of the day.

Enormous numbers of people are now employed in these shops, chiefly on repetition work, and while it is true that these numbers may vary from time to time according to the contracts in hand, &c., in most of them the only limit seems to be one of floor space. In

[1] Its influence with regard to tuberculosis would only be manifest when lighting of the work was so bad as to compel workers habitually to assume a cramped position while at work, thus restricting chest movements and pulmonary ventilation.

other words in each shop there are just as many people as the size of the machines and the nature of the work will permit. The workers sit or stand in long rows, and although often nearer to one another in the rows than is desirable the machine and work determine the actual distance; this however is rarely, if ever, dangerously near. The risk of a massive infection from another open case would be far more likely to occur when the rows which face one another are too near. This I never saw—three feet apart being the minimum distance observed, and rarely was it less than 3 ft. 6 in. or 4 ft. with in most cases, intervening machines at head level.

The nearest approach to a dangerous proximity is to be seen in some viewing and gauging departments, and in certain operations on very small articles or parts. In one such case a large roomful of girls were working with small drilling machines on friction tubes. They were so close together that their elbows could touch and even overlap one another.

On repetition work in A factories, only one departure from the linear arrangement of workers came under my notice. In the assembling of certain fuses sixty girls in one room sat in groups of four, their bent heads nearly touching. Such position and proximity is certainly undesirable, and could easily give rise to the infection of a susceptible individual were one of the group to have open phthisis. There was, however, no notified case here, nor was there known to have been a case in this room during the period of this particular operation.

Type B.

Under *B* are comprised older and usually smaller workshops. The chief determining factor has been their age—since it is rare to find a factory older than about twenty years which at all conforms to the standard of hygiene which is now known to be absolutely essential for health. Some of these have been built fifty years and more. Many of them have been enlarged to meet growing business by the promiscuous tacking on here and there of additions of various sizes, and in various positions. All suggestion of original design is thus lost. Daylight and sunlight are excluded from inner parts as well as access of fresh air, and nothing can improve or remedy such defects. Others originally standing free, have now become built up on one, two, or three sides, so as to be completely wedged in. In yet other cases adjoining premises which are quite unsuitable for factory purposes have been connected by means of doors and passages.

Roofs and ceilings are often very low, unduly restricting air space—windows are usually small, many are cracked and broken, all are usually very dirty, some absolutely opaque, and scarcely any can be properly opened. Owing to the peculiar disposition of stairways, passages, and doors some of these shops are extremely draughty and cold, while into others a current of fresh, moving outside air could not possibly be made to penetrate.

By reason of their darkness artificial lighting has often to be used all day: frequently this is by gas, in which case there is permanent overheating as well as some contamination of the air.

In nearly all of them the floors are of wood, badly laid, often very dirty, and in some cases actually in holes. Unnecessary ledges and projections abound, affording unlimited opportunities for the conservation of dust and dirt.

Many other defects in these shops could be enumerated, but sufficient has been said to show the ineradicable quality of those mentioned. Nothing short of demolition and rebuilding could convert them into such places as ought to be offered to those whose working days must be lived in them.

As regards numbers and position of workers in *B* factories, relatively to floor space these are practically the same as in Type *A*, that is to say every inch of space is occupied by workers. But since the cubical contents of these shops are so much less, and measures for changing and freshening the air in them are either defective or non-existent, the chances of workers as regards maintaining a high level of health while working in them will certainly be less favourable in comparison with those spending their working hours in *A* shops.

A special inquisition into the possibilities of *direct Tuberculous infection* through the agency of tools or materials, or in any other way, was made in each of the works visited (both in Class *A* and *B*), as well as into the question of spitting. As regards the latter practice, which is of course prohibited everywhere, though with varying degrees of severity, one could not fail to remark the exceedingly scanty evidence of it on the floors of stairs and passages, lavatories, W.Cs., and in any parts of these works as compared with other large workshops examined, in London and in the Northern Counties. Indeed in most of them there were no visible signs of it at all. Where chiefly women or women and girls alone are employed this is, of course, not remarkable. Closer inquiry, however, brought to light another practice which was known of everywhere, and which there was reason to think may be followed to a greater or less extent in all of them. I refer to what is here known as 'spitting in the suds', i.e. spitting into the receptacles which hold the lubricant mixture found in all shops where 'wet' metal work is done. It is a disgusting and possibly a dangerous habit, since this mixture is frequently sprayed on to people's clothes, and the hands of workers are constantly wet with it. Whether its causticity and the disinfectants which are added to it in some works are a sufficient safeguard, experimental research alone could show.

As regards the materials and tools used—the nature and physical properties of the former (viz. the non-ferrous metals) practically preclude the possibility of tuberculous sputum adhering to it, and the same may be said with regard to tools, gauges, &c., which are all of metal.

No evidence of any dangerous 'trade habit' such as occurs in certain industries was discovered which could be instrumental in transmitting this infection from one operative to another.

Table IV shows the distribution of cases between factories referable to the two main types *A* and *B*. It will be noticed that whichever basis of population be adopted that of 1914 or that of 1917 the proportion of the cases visited which is derived from *B* factories is considerably greater than one would anticipate upon the basis of population alone. Thus the cases are in the ratio of 1·9 to 1, as between *A* and *B* factories, while the 1914 populations are in the ratio of 3·4 to 1, and the 1917 populations in the ratio of 10·3 to 1. Much weight cannot perhaps be assigned to this discrepancy[1] but it is consistent with the view above developed that the general circumstances of the *B* factories are unfavourable to health.

Certain particulars were ascertained bearing upon hereditary tendency. They are set out in Table V. which shows that in 43 cases or **26·54 per cent., other cases of tuberculosis in these** families have been notified, or there have been deaths of other members of the family from this cause, and in some cases both deaths and other cases.

In considering the etiology of tuberculosis while in the past doubtless too great a share has been attributed to heredity it will be admitted by all observers that what in comprehensive phrase has been called 'soil' at least plays an important rôle therein. This much it is at any rate safe to say that while possibly no one, given sufficiently prolonged or repeated exposure to the contagion of tuberculosis can be looked upon as being totally invulnerable, on the other hand we undoubtedly find that certain individuals and certain families appear to be much more susceptible than others.

But since infection is possible at any age, and the possibility of latency being admitted, it is obvious that until all the offspring of any tuberculosis-tainted union have completed their span of life our information as regards heredity (even for such single unit of a generation) **cannot be complete.**

Again, in the cases now under consideration the insuperable difficulty arises that in respect of heredity these actually constitute *a partial sample*, **referring as they do solely to families in which we** have the definite information that at least one case of tuberculosis has occurred. No study or consideration of these families alone can afford us any just criterion as to proportion in the matter of heredity. In order to determine this obviously we must have for comparison or control one or more samples of equal size and of like content (that is to say, samples strictly comparable in respect of sex, age periods, social status, &c.) but made up of individuals who have not been notified for tuberculosis. Inquiries would then have to be made as to heredity in the families of all these individuals, and then a comparison instituted between these groups. This question, however, was not included among—was no doubt intentionally excluded from—those asked on the cards.

[1] In terms of total notifications per 1,000 of average populations 3·1 to 1 and the notifications over 1914–17, the populations 1914–17.

Table IV. A. Factories.

Administrative County or County Borough.	Number of Factories in 1914.	Number of Factories in 1914 liable to Special Supervision.	Notified Cases of Poisoning investigated.			Notified Cases during the whole Period of Notification, 1911-17.		
			Number of Cases.	Males.	Females.	Males.	Females.	Total.
1	118	242	3	0	3	0	4	4
2	756	502	4	2	2	3	3	6
3	897	1,472	20	14	6	12	6	18
4	905	11,869	1	0	1	32	30	62
5	1,198	366	7	4	3	9	8	17
6	1,126	8,137	5	1	4	30	28	58
7	1,343	20,151	11	2	9	77	17	94
8	1,454	1,253	14	14	0	18	0	18
9	1,784	4,071	10	2	8	3	10	13
10	2,402	1,171	3	1	2	47	37	84
11	1,284	6,156	2	1	1	86	3	89
	15,270	56,702	107	66	41	267	136	403

Table IV *a*. B. Factories

Number of Factory	Number of Employés on 1914	Number of Employés on 1917 (1st February)	Notified cases of Tuberculosis (non-fatal).			Notified Cases (non-fatal) of other forms of Notifiable Disease, 1914–17.		
			Number of cases.	Males.	Females.	Males.	Females.	Total.
2	110	70	1	0	1	0	1	1
13	245	170	2	0	2	0	2	2
14	304	175	1	0	1	1	4	5
15	174	180	2	2	0	2	1	3
16	425	670	13	3	10	15	3	18
17	450	500	9	8	1	9	1	10
18	457	400	8	2	6	9	0	9
19	438	600	3	3	0	3	2	5
20	386	132	2	1	1	6	0	6
21	650	208	9	5	4	6	5	11
22	500	320	1	0	1	4	1	5
	1,861	1,420	55	27	28	58	24	82

Table V gives under their initials for each sex the 43 cases in which either one or more relations are known either to be suffering from or to have died of tuberculosis.

Table V.

F. = father. M. = mother. B. = brother. Si. = sister. So. = son. D. = daughter. U. = uncle. A. = aunt. GF. = grandfather. GM. = grandmother. W. = wife.

Males 22 Cases.			Females 21 Cases.		
Initials.	*Relatives dead from Tuberculosis.*	*Relatives suffering from or known to be suffering from Tuberculosis.*	*Initials.*	*Relatives dead from Tuberculosis.*	*Relatives suffering from or known to be suffering from Tuberculosis.*
— D.	GF.	F., Si.	E. I.	F.	M.
R. W.	B. — So. (2	S.	E. E.	F., Si.	
J. C.		B.	E. C.	...	D.
J. B.	Si.	..	A. A.		B.
A. W.	F.		D. B.	F.	
— S.	...	D.	A. R.	GF., B. (2), Si.	..
H. A.	F.	B., Si.	— H.	F.	
G. B.	.	B., Si. (2	D. B.	M.	
W. T.		So. (2	L. S.	..	F.
E. J.	.	B.	S. L.	M., B.	...
T. J.		B.	— H.	F.	...
T. H. B.	So. (2	W.	— P.	A.	...
W. B.	B.	...	A. S.	B.	
A. T.		W., S.	A. E.	M., F.	
W. B.	B. (2	.	M. D.	..	B., Si.
W. S.	M.	.	L. H.	M.	D.
H. T. B.	...	So.	F. B.	F.	M.
G. C.		W., So.	A. B.	..	B., Si.
E. B.	.	D.	— B.		F.
G. E. L.		B. (2), A.	G. L.	GM., A.	
G. J.		M., Si. (2	M. A.	B., S.	
— T.	U. (2	B., Si.			

Table VI gives details with regard to contacts, or possible sources of infection in the home: that is to say, that in addition to the person named on the card it was ascertained that there was also, living in the same house, in certain instances one or more other persons suffering from tuberculosis (the majority were notified cases).

Among the 162 cases analysed there were 52 such instances, or 32 per cent., distributed as follows:

Table VI.

Number of contacts.	No. of Instances.	No. of Persons.	Proportion per cent. of Instances.	Proportion per cent. of Persons.	Average number of contacts per Instance.
One or more contacts	52	33	20·4	19	1·1·6
One contact	31	19	11·6	12	7·4
Two contacts	17	10	6·1	7	4·5
Three contacts	3	4	2·4	0	
One contact definite, with one or more others probable	10	10	6·1	0	..
One or more contacts reported but not verified	6	4	2·4	2	1·—

7 & 8 VII gives the localities in which the 162 persons under consideration were domiciled. For the following reasons it may be looked upon as affording some measure, though necessarily but a rough one, of their housing conditions.

Birmingham for municipal purposes is divided into 30 wards. For sanitary administrative and statistical purposes (particularly with reference to zymotic disease incidence) these have been grouped into three areas, known respectively as the Central Wards, the Middle Ring and the Outer Ring. In the first of these groups it is well known that there is much crowding of the population and that industrial housing conditions are the worst in Birmingham. These tend to improve somewhat in the middle zone, and still further to do so in the outer ring or suburban area, where there is necessarily more building space and room for expansion.

The housing generally of the Birmingham populace however is notoriously bad, and has long been so. So unsatisfactory indeed has it been that in 1901 public attention was drawn to the matter and again in May 1913 when a special Committee was formed by the City Council which was empowered to investigate thoroughly and to report upon the whole question. An interim Report was issued on October 20th 1914 and a passage from this may be quoted here since it contains the pith of the matter.

It reads: "Birmingham contains a vast number of small houses in courts and terraces, mostly of the back to back type. They are in many ways undesirable dwelling houses owing to the small size of their rooms the want of through ventilation, and in many cases to the fact that they get no sunlight. But much more important than these defects is the insufficiency and patchiness of their common conveniences which form the 'true social breeding centres', and make it difficult for the inhabitants to lead decent and healthy lives.

Reasons were given (which need not be gone into here) to show why these conditions were being maintained and the impossibility of looking for any amelioration of them except by making use of the powers of the Sanitary Authority. The outcome of this inquiry was the formation of a scheme for clearance and rebuilding in the central area and the acquirement of vacant areas for building more suitable houses and tenements in the outer ring and but for the war this would have been put into operation forthwith. Unfortunately however, for the present things remain as they were and that the above report and condemnation merely states the plain facts was fully borne out by this inquiry.

As regards the case incidence of tuberculosis it has been observed for many years now that this is highest in the central crowded area and decreases in the middle ring and still more so in the outer ring. For instance, in 1912 it was 2½ times as high in the central area as in the outer ring, in 1913 the averages for the Central, Middle and Outer wards were 7·3, 3·47 and 2·7 respectively, and in 1914, 5·4, 3·7 and 2·2 and though later figures have not been published, the Medical Officer of Health states that a similar ratio of case incidence has continued up to the present time.

In the cases here analysed the greatest number come from

houses in the middle ring, and the smallest from the outer. But had the above ratio been maintained, this must obviously have been purely accidental, for the number of cases examined (16) is a tiny fraction of the total case incidence; and here too other factors come into play, the one most likely to disturb the ratio being the fact that the largest of the shops visited happen to be situated in the middle ring, and the tendency there is in regard to all factories for the majority of workers to be drawn from streets and neighbourhoods as near to their work-place as possible.

Table VII.

Central Wards.

Name of Ward.	Number of Cases.	Males.	Females.
St. Paul	1	1	0
St. Mary	5	0	5
Duddeston and Nechells	17	10	7
St. Bartholomew	5	4	1
St. Martin and Deritend	1	1	0
Market Hall	0	0	0
Ladywood	7	5	2
Totals	39	23	16

Middle Ring.

Name of Ward.	Number of Cases.	Males.	Females.
Lozells	5	3	2
Aston	14	4	10
Washwood Heath	1	0	1
Saltley	11	4	7
Small Heath	28	21	7
Sparkbrook	6	6	0
Bordesley Heath	4	2	2
Edgbaston	2	0	2
Balsall Heath	3	2	1
All Saints	17	14	3
Total	91	56	35

Outer Ring.

Name of Ward.	Number of Cases.	Males.	Females.
Soho	0	0	0
Sandwell	0	0	0
Handsworth	1	1	0
Erdington, N.	0	0	0
Erdington, S.	0	0	0
Yardley and Hawkhills	0	0	0
Acock's Green	2	0	2
Sparkhill	0	0	0
Moseley and King's Heath	1	1	0
Selly Oak and Bournville	5	3	2
King's Norton and Stirchley	3	1	2
Northfield	2	1	1
Harborne	2	2	0
Quinton	4	4	0
Totals	20	13	7

The industrial occupation of women during the war has been suggested as a cause of the rise in the incidence and death rate from phthisis for females at certain ages which has occurred in England and Wales. Many more figures will be necessary before this problem can be satisfactorily solved, but industrialization would certainly seem to be by far the most striking and far reaching change in the conditions of daily life affecting large numbers of women at the ages concerned which the war has brought about, and the one best worth following up. The issue, however, is not quite a straight one, for although a rise appears when all England and Wales are taken together and in some cities the rise has been considerable, yet other important areas have shown none, or perhaps one should rather say have as yet shown none.

Birmingham is such a place. Prior to and up to the time of this investigation (November–December, 1917) the steady decrease which had been going on for some years in incidence and mortality rate, both for women and men at industrial ages, continued to be maintained. The last published report is for the year 1916, but interim quarterly returns were available up to the end of 1917. More recently still, however, industrial case returns (Notifications) for about the first three-quarters (8¾ months actually) of the present year (1918) are to hand, the total of which is already higher than that for 1917 complete. These returns also show for the factories investigated herein an increased case incidence in 50 per cent. of the A. factories, and in 54·5 per cent. of B. factories; and this with three and a half months of the year still to run—months too, in which case incidence is likely to be high. May it be then, it is fair to ask, that here also industrialization, or at least some influence affecting case incidence, will now begin to show itself?

Another view is possible in a place like Birmingham, which should not be omitted. Housing conditions among the working classes, and particularly in certain districts are admittedly bad. But factory conditions in the largest establishments, which give occupation to by far the greater numbers of munition workers, have been shown to be highly satisfactory. Not only so, but the health and welfare, as well as the feeding of immense numbers of these very people have been studied as never before, and during the entire period of their industrial occupation. To the question whether from the point of view of general health or risks of tubercular infection, it is preferable to spend eight hours of the day at work under such conditions as A factories supply, or in a four-roomed back-to-back house in a Birmingham court, there can be but one answer.

The chief observations made in this inquiry may now be very briefly summarized.

1. The works seen were of two types:

A. Large and modern ones, providing satisfactory hygienic conditions.

B. Smaller, of antiquated construction, and abounding in defects.

2. Relative crowding of workers everywhere. The effect of this is worse in the smaller places, on account of restricted fresh air and light, &c.

3. Ventilation thoroughly bad in B shops—not always satisfactorily solved in the best type. Windows not nearly enough made use of, and control of both heating and ventilation apt to be left in the wrong hands.

4. No evidence found of spreading of tuberculosis by *direct* contagion, neither by tools, materials nor by any 'trade habit.'

5. Entire absence of visible signs of spitting in places where usually seen in works—but

6. Habit known as 'spitting in the suds' said to be prevalent. This should be investigated and stopped.

7. Home housing conditions very unsatisfactory in many parts of town. Everything points to the home as being the place of actual infection either through contacts or immanent in the house itself.

General Summary of Conclusions.

1. The incidence of pulmonary tuberculosis upon particular occupations is greater than can be accounted for by the hypothesis that persons employed in such trades are *ab initio* of inferior physique and with a low general resistance to disease-producing causes.

2. The general statistics of employed women are insufficient to furnish a ground for exact reasoning as to variations of liability to contract tuberculosis.

3. The incidence of tuberculosis upon the inhabitants of towns is greater than can be accounted for by the general lowering of health associated with the home environment of the urban poor, and is consistent with the view that industrial employment introduces a special factor which makes for the development of tuberculosis.

4. The ratio of phthisis deaths to deaths from other causes in age groups is substantially correlated with the age death-rate from phthisis, and a tolerably exact impression of the level of phthisis mortality in a group of districts can be derived from the proportionate mortality index. In individual districts, however, the divergence may be considerable between the observed death-rate and that predicted from a knowledge of the proportionate mortality.

5. In the majority of English registration districts the proportionate phthisis mortality at ages 15–45 has increased since the outbreak of war.

6. The position of the maximum in the curve of proportionate mortality (women) is different, and has varied in a different way since the war, in towns of different kinds. This is manifested in the nearly uniform increase of the proportionate mortality (phthisis) at ages 15–20 in the great industrial towns, another result tending to suggest that the war-time increase of phthisis mortality is due to industrialization.

7. A field investigation in the Birmingham area discloses evidence (*a*) of a relatively greater incidence of phthisis upon the employees in hygienically unsuitable factories, (*b*) of a serious condition of overcrowding in industrial dwellings, but (*c*) no evidence of any specific trade habit amongst munition workers specially apt to favour the conveyance of phthisis from person to person.

NATIONAL HEALTH INSURANCE

MEDICAL RESEARCH COMMITTEE

An Analysis of the Results of Wassermann Reactions in 1,435 cases of Syphilis or Suspected Syphilis

LONDON:
PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE.
To be purchased through any Bookseller or directly from
H.M. STATIONERY OFFICE at the following addresses:
Imperial House, Kingsway, London, W.C. 2, and
28 Abingdon Street, London, S.W. 1;
37 Peter Street, Manchester;
1 St. Andrew's Crescent, Cardiff;
23 Forth Street, Edinburgh;
or from E. Ponsonby, Ltd., 116 Grafton Street, Dublin.

1919

Price 2s net

MEDICAL RESEARCH COMMITTEE

The following publications relating to the work of the Medical Research Committee can be purchased through any bookseller, or directly from H.M. Stationery Office, at the following addresses: Imperial House, Kingsway, London, W.C., 2, and 28 Abingdon Street, London, S.W. 1; 37 Peter Street, Manchester; 1 St. Andrew's Crescent, Cardiff; 23 Forth Street, Edinburgh; and from E. Ponsonby, Ltd., 116 Grafton Street, Dublin.

First Annual Report of the Medical Research Committee, 1914-1915. (Cd. 8101.) Price 3*d.*, post free 4*d.*

Second Annual Report of the Medical Research Committee, 1915-1916. (Cd. 8399.) Price 3½*d.*, post free 5*d.*

Third Annual Report of the Medical Research Committee, 1916-1917. (Cd. 8825. Price 6*d.*, post free 7*d.*

Fourth Annual Report of the Medical Research Committee, 1917-1918. (Cd. 8981.) Price 1*s.*, post free 6*d.*

Special Report Series

No. 1. First Report of the Special Investigation Committee upon the Incidence of Phthisis in relation to Occupations.—The Boot and Shoe Trade. Price 3*d.*, post free 4*d.*

No. 2. Report of the Special Advisory Committee upon Bacteriological Studies of Cerebro-spinal Fever during the Epidemic of 1915. Price 6*d.*, post free 7½*d.*

No. 3. Bacteriological Studies in the Pathology and Preventive Control of Cerebro-spinal Fever among the Forces during 1915 and 1916. Price 1*s.* 6*d.*, post free 1*s.* 8½*d.*

No. 4. Reports upon Investigations in the United Kingdom of Dysentery Cases received from the Eastern Mediterranean.

I. Amœbic Dysentery and the Protozoological Investigation of Cases and Carriers. Price 1*s.*, post free 1*s.* 2*d.*

No. 5. II. Report upon 878 Cases of Bacillary Enteritis. Price 1*s.* 6*d.*, post free 1*s.* 8*d.*

No. 6. III. Report upon recovered Cases of Intestinal Disease in the Royal Naval Hospital, Haslar, 1915-16.

IV. Report upon combined Clinical and Bacteriological Studies of Dysentery Cases from the Mediterranean. Price 1*s.* 6*d.* post free 1*s.* 8*d.*

No. 7. V. Report upon 2,360 Enteritis 'Convalescents' received at Liverpool from various Expeditionary Forces. Price 2*s.*, post free 2*s.* 2½*d.*

No. 8. Report upon Soldiers returned as Cases of 'Disordered Action of the Heart' (D.A.H.) or 'Valvular Disease of the Heart' (V.D.H.). Price 1*s.* post free 1*s.* 1½*d.*

No. 9. A Report upon the use of Atropine as a Diagnostic Agent in Typhoid Infections. Price 1*s.*, post free 1*s.* 1½*d.*

No. 10. The Mortalities of Birth, Infancy and Childhood. Price 1*s.* 6*d.*, post free 1*s.* 8*d.*

NATIONAL HEALTH INSURANCE

MEDICAL RESEARCH COMMITTEE

An Analysis of the Results of Wassermann Reactions in 1,435 cases of Syphilis or Suspected Syphilis

Approved for Publication by the Medical Research Committee,
17 January, 1919

Medical Research Committee.

(National Health Insurance.)

The Hon. WALTER ROCH, M.P. *(Chairman.)*

The Right Hon. CHRISTOPHER ADDISON, M.D., M.P.

The VISCOUNTESS GOSCHEN, C.B.E. *(Treasurer.)*

C. J. BOND, C.M.G., F.R.C.S. *(Hon. Colonel).*

Professor WILLIAM BULLOCH, M.D., F.R.S.

HENRY HEAD, M.D., F.R.C.P., F.R.S.

Professor F. G. HOPKINS, D.Sc., F.R.S.

Major-General SIR WILLIAM LEISHMAN, K.C.M.G., C.B., F.R.S.

Professor NOEL PATON, M.D., F.R.S.

SIR WALTER M. FLETCHER, K.B.E., M.D., F.R.S. *(Secretary.)*

15, BUCKINGHAM STREET,
STRAND, W.C. 2.

WELLCOME PRINTING STAFF, O.L.F.

INTRODUCTION

The Medical Research Committee are indebted to the Medical Department of the Admiralty for permission to publish in the present form this analysis of the results of the Wassermann reaction obtained in a large number of cases of syphilis or suspected syphilis. The outcome of this joint work by Surgeon Lieut.-Commander Fildes, whose services have been supplied by the Committee during the war for direction of the pathological work at the R.N. Hospital at Haslar, and by Surgeon Lieut.-Commander Parnell, is particularly opportune at the present time. It comes to supplement the report upon the diagnostic value of the Wassermann test recently issued by the Committee,[1] in which a review of other efforts towards determining the value of the test is given, with references to previous significant publications, together with an account of a special inquiry initiated by the Committee. In this the results of Wassermann tests performed by three well-known workers in a given series of cases were compared with the findings of a highly skilled observer from the clinical standpoint. The comparison supported the conclusion that 'the percentage of positive Wassermann reactions in active syphilis is so high that the test may, for all practical purposes, be looked upon as specific'.

In the present analysis by Surgeon Lieut.-Commanders Fildes and Parnell the same question is approached in another way. Their method is to put side by side the routine clinical and pathological records of over 1 400 unselected men who, in the circumstances, were available for close and repeated observation. The results given should be read in connexion with the recent report just mentioned. It will be seen that two conclusions emerge clearly from the analysis of the observations, one as to the value of negative reactions, the other as to the value of positive reactions. As the authors point out, the evidence obtained shows that 'negative reactions in cases of syphilis which exhibit manifest signs are very rare whether they have been treated or not and thus the negative test is of very great significance in the exclusion of a diagnosis of syphilis'. At

[1] Reports of the Special Committee upon the Standardization of Pathological Methods, No. IV. 'The Diagnostic Value of the Wassermann Test.' Medical Research Committee, General Report series, No. 21.

the same time it has been found that of 1,177 men who gave positive reactions, 1,112 showed more or less conclusive evidence of syphilis. Of the remaining 65, while there was no direct conclusive evidence either for or against the presence of syphilis it could be said that all of these men were (or had been infected) with venereal disease and therefore that their condition was not inconsistent with diagnosis of syphilis. On these grounds the authors will be regarded as justified in claiming that 'the overwhelming importance in diagnosis of a positive Wassermann reaction is beyond reasonable dispute.

Medical Research Committee,
15, Buckingham Street,
Strand,
W.C. 2.

20 January 1918.

AN ANALYSIS OF THE RESULTS OF WASSERMANN REACTIONS IN 1,435 CASES OF SYPHILIS OR SUSPECTED SYPHILIS

BY

HON. SURGEON LIEUTENANT-COMMANDER P. FILDES, R.N.V.R.,
Assistant Bacteriologist to the London Hospital,
Senior Medical Officer, Laboratory, R.N. Hospital, Haslar

AND

SURGEON LIEUTENANT-COMMANDER RODERICK J. G. PARNELL, R.N.,
Senior Medical Officer, Venereal Section, R.N. Hospital, Haslar.

CONTENTS

PAGE

I. INTRODUCTION 1

II. THE MATERIAL ANALYSED 7

III. THE EVIDENCE OF SYPHILIS WHICH IS ASSOCIATED WITH POSITIVE WASSERMANN REACTIONS 9

IV. THE EVIDENCE OF SYPHILIS OBTAINED IN THOSE CASES WHICH GAVE POSITIVE WASSERMANN REACTIONS 13

V. THE EVIDENCE OF SYPHILIS OBTAINED IN THOSE CASES WHICH GAVE NEGATIVE WASSERMANN REACTIONS 14

VI. CASES OF SYPHILIS TO WHICH SPECIAL REFERENCE IS MADE IN THE TEXT 14

VII. TABLES OF CASES TO ILLUSTRATE THE EVIDENCE OF SYPHILIS OBTAINED 16

VIII. DISCUSSION 42

I. INTRODUCTION

THE object of the present report is to show how the results of the Wassermann reaction compare in routine practice with the clinical findings. The improvements which have taken place in the technique of the reaction require that information upon this subject should be revised. In the literature[1] it has been the custom to show that such and such a percentage of primary, secondary, or tertiary syphilitics give positive Wassermann reactions, but considerable variation exists in the reports of the various workers, particularly in what are described as 'latent' cases. To any one, however, who is engaged in the practical study of these questions and proposes to divide a large material

[1] See, for instance, Notes on the Wassermann Test. *Medical Research Committee, Special Report Series*, No. 21. Harrison & Sons, London, 1919.

into these categories it soon becomes apparent that the number of borderline cases is so large that they exert a considerable influence upon whichever group they are placed in. The percentage figure of positive results obtained in any group then becomes a more hard and fast figure than the data warrant. It therefore appears to us to be unsatisfactory to attempt to group cases into 'stages.'

Further, many of the publications in the literature have always appeared to us to be open to a certain degree of suspicion. It is customary to give lists of 'control cases', that is persons suffering from a variety of non-syphilitic diseases, in order to show that none of these diseases give positive Wassermann reactions.

We do not ourselves understand how this can be done in a purely *bona fide* manner, since any list of persons suffering from any type of disease always shows a certain percentage of positive results, and if these positives were credited to the disease in question the value of the Wassermann reaction would appear to be trivial. If they are not so credited they should not be merely left out without any explanation. The most notorious example of this difficulty is met with in Gonorrhœa, a disease which always figures largely among the controls. Now many cases of Gonorrhœa give positive Wassermann reactions, and as will be seen later, in some of these no evidence of syphilis can be obtained. Nevertheless in the literature cases of Gonorrhœa always give negative reactions.

Under such circumstances it appears to us to be useless to give lists of diseases with thousands of Wassermann reactions, because in most of the inevitably positive cases no evidence of syphilis would be obtainable from our records.

We propose to approach the question from a different standpoint, and, instead of producing hard and fast tabulations of material which cannot be so tabulated with strict impartiality, we intend to compare the results of the tests with the actual clinical findings, and where these do not agree we assume that we are dealing with a reasonable reader who does not forget that syphilis is a very prevalent disease and that one man can suffer from two complaints.

This report naturally divides itself into two parts. We have before us the clinical and pathological records of some 1,400 men. Of these a number gave positive reactions, and we propose to review the clinical evidence which is available to confirm these positive results. From this we shall deduce that evidence of syphilis is available in a sufficiently large number to warrant the assumption that all of the positive men really had syphilis, in fact that a positive reaction actually indicates syphilis.

On the other hand, a number of men gave negative reactions, and we shall investigate their cases to find out if any, and if so how many, of these were syphilitic. We shall then be in a position to say that no cases—or very few cases—of syphilis give negative results, and thus if a test is reported negative in a man suspected of syphilis it will be more or less improbable that the case is one of syphilis.

It appears to us that evidence of this nature is more convincing than a table of results, which must always be under suspicion when no clinical illustrations accompany it.

II. The Material Analysed

The series of Wassermann tests under survey consists of the *first* 'diagnostic' examination made in this hospital upon *every* man admitted into the venereal section for syphilis or suspected syphilis. In some cases this test was performed while the man was still at duty in a local establishment.

The investigation is confined to those men whose cases are entered upon the card index system, since the former method of recording was too cumbersome to analyse. Thus it consists of *every* man who was admitted between October 1, 1917, and June 30, 1918, and in addition a few rather older cases who have not been readmitted but who happen to have come under observation again and have been 'written up' on cards from the old notes.

No selection of cases has been made. None have been omitted.

The routine procedure by which the cases analysed are collected is as follows:

(*a*) Cases are admitted direct to the Venereal Section with diagnoses of syphilis made in local establishments without any laboratory tests having been applied. The Wassermann test which is then carried out is the one under review.

(*b*) Cases are admitted from ambulance trains with a diagnosis of syphilis made in another hospital. These have often received a small amount of treatment. They are subjected to the Wassermann test before further treatment, and this is the test under review.

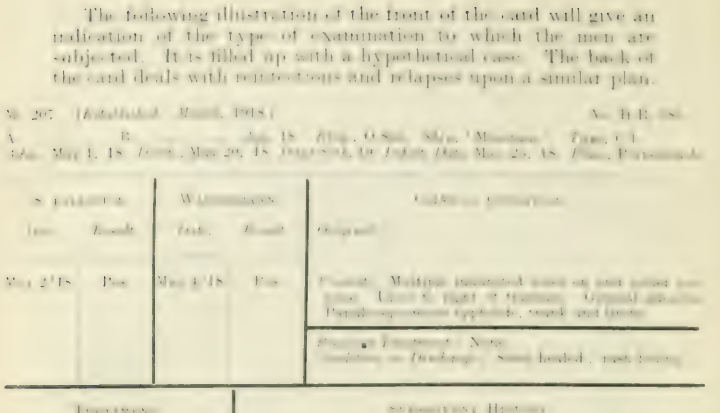
(*c*) Cases are admitted which have been diagnosed as syphilis on the strength of a Wassermann test carried out by us before admission. This test is then the one to be reviewed.

(*d*) A number of cases are admitted in which *S. pallidum* has been found either by us or the Medical Officers in outside establishments. These are as a routine subjected to the Wassermann test after admission, and this is the one selected for review.

Unfortunately many of the men admitted with venereal sores had been treated outside with local antiseptic applications, and thus tests for *S. pallidum* often failed.

Every man admitted is examined according to a set routine, and the particulars are entered upon a card. This is designed not to collect a mass of detail which has ordinarily little diagnostic value, but to record the important features of every case upon a set plan which is convenient for the collection of mass statistics. All applicable laboratory tests are carried out as a routine, and every man is now lumbar punctured. In many of the cases in which the lumbar puncture shows evidence of nervous disease, neurological and ophthalmological examinations are also made.

The following illustration of the front of the card will give an indication of the type of examination to which the men are subjected. It is filled up with a hypothetical case. The back of the card deals with reinfections and relapses upon a similar plan.



The number H.R. 385 is the man's reference number which is inscribed upon the syphilis papers which he carries with him. It is used in connexion with the 'follow up' system which ensures as far as possible that we are kept informed of the subsequent history of the man in particular in connexion with subsequent Wassermann tests (*vide* Fibbs and Parnell, *Journ. of the Royal Naval Medical Service*, July 1918).

The 'Type, C.I.' indicates that the man is a 'C' case and has been treated by us with the number 1 course of treatment.

A classification of cases of syphilis into 'stages' results in the discovery of so many borderland cases that, for statistical purposes, we divide our material upon a time basis or upon a basis which combines a time- and clinical-factor.

Thus an 'A' case is a man with an inoculation lesion in whom the Wassermann reaction has not yet become positive.

A 'B' case is a man with an inoculation lesion or with a history of an inoculation lesion but with no other signs or history of general infection except glandular enlargement and a positive Wassermann reaction up to and including 18 months from the date of infection.

A 'C' case is a man with signs or history of general infection, including a positive Wassermann reaction up to and including 18 months from the date of infection.

A 'D' case is a man with or without symptoms or signs over 18 months from the date of infection.

It will be observed that type A and B cases include all instances of 'primary' syphilis. C cases are the acute or recent cases of 'secondary' syphilis, but some early 'tertiary' lesions come under this category; while D cases include not only late 'secondary' but 'tertiary' and most 'latent' infections: further, this category also includes those cases which are ordinarily impossible to classify, namely men with a healed inoculation lesion in whom no signs of generalization have appeared although the infection was over 18 months before.

From the point of view of treatment the most important factor to determine is the time factor, and therefore we make special efforts to decide the probable date of infection and do not attempt to determine whether a man is a 'late secondary' or a 'tertiary' case. As for the expression 'latent', this is a misconception, and altogether ignores the fact that all who show a positive Wassermann reaction have active syphilitic lesions whether externally detectible or not.

The technique used in the carrying out of the Wassermann reaction is that of Fildes and McIntosh, described in the Interim Report of a special committee of the *Medical Research Committee* upon the standardization of pathological methods. (Special Report Series, No. 14, 1918.)

III. The Evidence of Syphilis which is Available to control the Wassermann Reaction.

It will be understood that great difficulty is inevitable in attempting to find evidence of syphilis in many cases which give positive Wassermann reactions.

This is very largely due to the fact that this reaction is accepted so completely as conclusive evidence of syphilis that in the hurry of routine work minor points are often not recorded, and it must be remembered that we are not now dealing with *cases* but with *records*, and the evidence we are seeking must be found, or not, as it stands in the records of the routine examinations.

We cannot make accessory examinations to clear up obscure points or make further inquiries from men who have passed far beyond our control.

It is first of all necessary to determine accurately what may be accepted as conclusive evidence of syphilis and what as sufficiently conclusive or suggestive evidence.

The only conclusive evidence of syphilis is the demonstration of *S. pallidum* in one of the lesions of the disease, but it is not practicable to confine the diagnosis to such narrow limits as this.

We are bound to follow the same lines of evidence which have been in use for centuries in the diagnosis of this disease, but we have by design weighed this evidence in an especially critical manner, in order that it may not be said that we have accepted trivialities as evidence of syphilis. We are of opinion that what we have accepted as evidence of syphilis cannot reasonably be disputed.

Most reliance has been placed on the following points :

(1) *The presence of S. pallidum.*

When *S. pallidum* has been demonstrated by us or by other observers whom we know to be reliable, we accept this as conclusive evidence of syphilis.

(2) *Clinical signs.*

(*a*) *Venereal sores.*—We cannot attach any value to a venereal sore as evidence of syphilis, unless it presents the characters known as 'Hunterian'.

A 'Hunterian' sore we accept as conclusive evidence of syphilis, but all other sores, whether 'indurated' or not, are not of conclusive diagnostic importance unless *S. pallidum* can be demonstrated in them.

In a naval clinic such as this practically every man can give histories of 'chancroids' or 'sores', and numberless examples of these conditions may be observed. By physical examination it is not possible to detect which are due to *S. pallidum* and which are not; the most unlikely looking 'soft sores' are found to contain *S. pallidum*, while definitely indurated ulcers fail to present any evidence of syphilis, either at the time of examination or later.

Therefore we pay no attention to such conditions in this review unless they contain *S. pallidum* or exhibit Hunterian characters.

Unfortunately a considerable proportion of these cases are still treated with local antiseptics before they come under hospital observation, and these applications very largely reduce the value of the negative spironeme test. It is found that in any untreated sore the existence of syphilis may be almost ruled out if spironemes are not found at two examinations by the dark ground method; but when the sore is treated this is no longer the case, and thus a number of our cases which give positive Wassermann reactions with sores on the penis as the sole suspicion of syphilis are deprived of the only definite test by which the diagnosis can be established.

Again, it is a common practice for medical officers who are not in a position to apply spironeme tests to give a man a dose of Galyl and then send him to hospital for further treatment. The evidence upon which the sore was thus diagnosed as syphilitic may or may not have been good, but in any case this evidence is seldom transmitted with the patient in a form which can be accepted as conclusive. Thus we are confronted with a further series of cases, which upon arrival have been treated, and show as the only evi-

dence of disease a healed or healing sore. When these, upon examination, show a positive Wassermann test we have no means of judging the accuracy of the result.

In all of such treated cases when the Wassermann reaction is positive we are of course compelled to continue treatment, but when the reaction is negative we discharge the patient under an organization for further observation until the diagnosis is more obvious.

(b) Cutaneous exanthems. Lesions of the mucous membranes and other signs of generalized syphilis. The characteristic signs of generalized syphilis, whether late or early, may of course be taken as conclusive evidence. Only in the case of general glandular enlargement do we make an exception.

General adenitis is a characteristic feature of syphilis, but is present to a variable degree in different cases. Since this condition is often observed alone as the only clinical sign of disease, we think it better to exclude slight degrees of general adenitis and only accept it as conclusive evidence of syphilis when it is recorded as being 'marked'.

(c) Abnormalities of the central nervous system. - We have found that by means of lumbar puncture and an ophthalmoscopic examination of the eye grounds, evidence of disease may be detected when all other methods fail. Such lesions are accepted as conclusive evidence of syphilis.

(3) *'Histories' of syphilis.*

As already indicated histories of venereal disease may be obtained from a large number of naval ratings, and thus such histories cannot be accepted as evidence of syphilis unless supported by exact details of the original condition.

When a man has a history of a 'sore on the penis' alone we reject the evidence, but when he has a history of a sore followed by a rash and sore throat or some other definite characteristic of syphilis we accept this as conclusive evidence, although it is, of course, only relatively conclusive.

Again, if a man is described as having had a sore on the penis which has appeared to the doctor who saw him at the time to be sufficiently characteristic to warrant a course of arsenical or even mercury treatment we are bound to accept this fact as evidence of syphilis.

It will be understood that in many of these cases *S. pallidum* was found at the time of treatment, but the written records which accompany the men are usually fragmentary and these facts are often omitted.

(4) *The Wassermann reaction.*

We consider that it is not illogical to bring forward previously or subsequently performed Wassermann tests as evidence of the correctness of that carried out upon admission to hospital.

In theory it would appear inadmissible to cite the test itself as evidence when the test itself is being proved, but it is impossible

to disregard confirmatory reactions entirely. The accuracy of the Wassermann reaction is, after all, accepted by the vast majority of authorities upon this subject, and the object of the present review is chiefly to show how it operates in practice in a large routine series of cases, and to demonstrate that there is no evidence to support the suggestion that it is prone to relatively frequent anomalies.

In the Interim Report of the Sub-committee of the Medical Research Committee examining this question (Special Report Series, No. 14, 1918) it is suggested that when a positive Wassermann reaction is the sole evidence of syphilis (detected by the particular observer who makes the clinical examination) it should be repeated, and if still positive it may then be accepted as proof of syphilis.

On these grounds we feel justified in accepting positive reactions performed outside the hospital before admission as proof of the correctness of our own test, and, similarly, the results of supplementary tests carried out by us after admission or after discharge to duty.

Unfortunately the number of cases is small in which this supplementary evidence can be adduced, because very few of the men have had Wassermann tests applied before admission, and if they had they were often negative. The men frequently were suffering from suspected primary syphilis with sores treated with antiseptics and were only admitted to hospital when we had demonstrated the existence of the positive reaction for the first time.

Again, since all cases when found to have a positive reaction were immediately subjected to intensive treatment, most of the tests which we were able subsequently to apply, gave negative results. As a routine they were only repeated when in our experience they were expected to give this negative result, namely **three months after treatment.**

In practice, therefore, it was only occasionally that we were able to make use of this supplementary evidence, namely in 61 cases in which this was the only direct evidence of syphilis.

(5) *The effect of treatment*

The effect of anti-syphilitic treatment upon the manifest signs was of very little value to us as evidence of syphilis, because it was not necessarily carried out alone. In practically every case observed the lesions resolved, or were resolving, before discharge **from hospital.**

When dealing with soft sores in a patient who gave a positive Wassermann reaction, local treatment was always applied in addition to the anti-syphilitic treatment, and therefore it was not possible to differentiate between the curative effect of these two procedures.

If the effect of treatment is to be accepted as evidence of syphilis, it may be said to have been positive in practically every instance.

(6) *Relapses.*

When a man has a lesion which is treated as syphilitic on the sole evidence of a positive Wassermann reaction and subsequently develops obvious symptoms of syphilis as a relapse, this is to be accepted as conclusive evidence that the original lesion was syphilitic.

These occurrences were, however, so few in our series that they are of little or no assistance.

(7) *Previous apparently non-syphilitic venereal disease.*

When it is admitted by a man that he has had gonorrhœa, 'chancroids', or buboes, or when he shows definite evidence of such venereal diseases, it can be assumed that he *may* also have had syphilis. There was, however, hardly a man in the whole series who failed to give positive indications of this sort, and thus it cannot be used in evidence except to show that the history of all the men was consistent with a diagnosis of syphilis.

IV. The Evidence of Syphilis obtained in those Cases which gave Positive Wassermann Reactions.

1,177 men were found to give positive Wassermann reactions and the following is the confirmatory evidence of syphilis:

(A) 938 men were conclusively shown to be syphilitic by reason of the presence of *S. pallidum* or clinical signs or histories of a generalized condition characteristic of syphilis (*vide* Table 1, p. 16).

(B) 62 men were accepted as syphilitic on the evidence of anti-syphilitic treatment having been previously applied for local venereal conditions which in the opinion of the medical officer responsible for treatment were syphilitic (*vide* Table 2, p. 26).

(C) 16 men were shown to be syphilitic by means of lumbar puncture and ophthalmological examination (*vide* Table 3, p. 30).

(D) 5 men were shown to be syphilitic by methods B and C (*vide* Table 4, p. 30).

(E) 61 men were accepted as syphilitic by reason of previous or subsequent positive Wassermann reactions (*vide* Table 5, p. 32).

(F) 4 men were diagnosed by methods C and E (*vide* Table 6, p. 34).

(G) 23 men were diagnosed by methods B and E (*vide* Table 7, p. 34)

(H) 3 men were diagnosed by methods B, C, and E (*vide* Table 8, p. 38).

(I) 65 men remained with positive Wassermann reactions in whom no direct evidence of syphilis was demonstrable (*vide* Table 9, p. 38).

V. The Evidence of Syphilis obtained in those Cases which gave Negative Wassermann Reactions.

258 men gave negative reactions, and the following is the evidence of syphilis obtained:

(*a*) 127 men had sores which contained *S. pallidum* (*vide* Table 10, p. 42).

(*b*) 34 men had sores or scars of sores which had contained *S. pallidum* or had been diagnosed as syphilitic and had been treated (*vide* Table 11, p. 44).

(*c*) 5 men had sores in which *S. pallidum* was not found, but they subsequently developed syphilis (*vide* Table 12, p. 46).

(*d*) 1 man had manifest secondary syphilis (*vide* p. 14 *infra*).

(*e*) 2 men had manifest tertiary syphilis (*vide* p. 15).

(*f*) 2 men had cerebro-spinal syphilis (*vide* Table 13, p. 48).

Thus conclusive evidence of syphilis was obtained in 171 of the negative cases.

(*g*) 11 men had no active lesions or non-syphilitic lesions, but a definite history of syphilis (*vide* Table 14, p. 48).

It may be assumed that several of these were cured and no longer syphilitic.

No evidence of syphilis was obtained in the 76 remaining men who gave negative reactions. They may be classified as follows:

Non-syphilitic cases.—23 men with sores which were not treated but they did not develop syphilis (*vide* Table 15, p. 50).

Undiagnosed cases.—45 men had similar conditions, but they did not come under observation again.

Doubtful cases.—8 men were said to have syphilis, but no signs of syphilis were present.

VI. Cases of Syphilis to which Special Reference is made in the Text.

The following is the only case of manifest secondary syphilis in which the Wassermann reaction was negative. It will be observed that the man was no longer in the acute stage, but the condition was partially resolved after mercurial treatment.

Case No. 254.

Infected 15th June, 1917.[1] Original lesion, sore on penis treated with "several mercurial injections" and black wash. Examination for *S. pallidum* on the 6th, 7th, and 9th November, 1917, negative. Physical examination on 29th November, 1917. Scars of sores on body of penis, prepuce, and glans. Marked general adenitis. Condylomata ani. Mucous patches on tonsils. Bubo right groin. W. R.[2] negative on 30th November, 1917, and

[1] Throughout this paper the probable date of infection refers to infection with syphilis if the man had syphilis. When a man has "soft sores" or gonorrhœa with no evidence of syphilis, this date usually refers to infection with these non-syphilitic diseases.

[2] For explanation of symbols used in the text, see p. 16.

on the 28th December, 1917. Treated with 0·9 grm. '914' on 29th November, 1917, on 3rd December, 1917, and on 3rd January, 1918. Lesions resolved.

We may also insert the following as a further example of this rare condition, although it does not come into the series under review.

Case No. 1658.

Infected March 1918. Never had a sore on penis. Rash first noticed in July. Treated with one small dose of Galyl on 23rd July. Examined 27th July, 1918. Very marked general adenitis. Fading discrete maculo-papular syphilide. Gonorrhœa and epididymitis. 2 lymphocytes and negative Wassermann reaction in the cerebro-spinal fluid. Treated with 2·7 grms. of '914' in 6 doses from 28th July to 13th August. A skin Herxheimer reaction and rise of temperature followed the first dose. On the 9th August the Wassermann reaction in the serum was negative. It had not been tested before. It was also negative on 6th September.

The following are the only two instances of negative reactions occurring in cases of manifest tertiary syphilis :

Case No. 46.

Infected in June 1917. Original signs not stated. On 17th September, 1917, the Wassermann reaction was positive; treated with 1·2 grms. Galyl from 3rd to 21st September. Examined 18th October, 1917. Deep gummatous ulcer inside right cheek. General adenitis. On 26th October, 1917, the Wassermann reaction was negative. Treated with 3·15 grms. '914' between 19th October and 4th November, 1917. Ulcer healed in 4 days. The Wassermann reaction was positive on 1st February, 1918.

Case No. 1271.

Infected in (?) 1911. Sore on glans penis. (?) Treatment. Examined 17th May, 1918. Ulcers on legs. Scars of abscesses on legs. Recent erosion at site of original sore on glans. On 17th May the Wassermann reaction was negative, but on 31st May it was positive. No arsenical treatment, but mercury was administered. Ulcers healed.

One further case, No. 1191, gave a negative reaction but no manifest active lesions were present, only the scars of old lesions.

Case No. 1191.

Infected 1910. Sore on penis and sore throat followed by ulceration of the palate. Treated with mercury pills for two years. Examined 9th May, 1918. General adenitis. Soft palate destroyed by previous ulceration. Posterior pharyngeal wall scarred and perforated. Old iritis in left eye. 4 lymphocytes and a negative Wassermann reaction in the cerebro spinal fluid. Treated with 2·7 grms. '914' between 10th and 25th May. On 17th May the Wassermann reaction was negative, but one week later it was positive (*vide* Table 14, p. 50).

VII. Tables of Cases to illustrate

Table I. *Unselected Examples of Men with Positive Wassermann*

Hosp. No.	W.R. Date.	Result.	S. pal.	Clinical	C.S.F. Cells.	C.S.F. W.R.	Eyes
				Proved Evidence of Syphilis			
766	8. 3.18	P		Large ulcer on body of penis L. Papular syphilides	2	0	
328	3. 4.18	P	P	Sore on prepuce L.			
742	21. 1.18	P	—	Nil.	0	0	—
124	28.10.17	P		Nil			
149	13.11.17	P		Subcapitular sore. Marked general adenitis. Papular syphilide.	—	—	
1018	12. 4.18	P		Sore ulcer on prepuce R. Marked general adenitis.	2	0	
1026	4. 4.18	P		Squamous papular and tubercular syphilide	4	—	—
1410	14. 6.18	P	P	Balanitis. Erosions at edge of prepuce and on glans. Subpreputial warts. Early papular syphilide	2	0	
318	21.12.17	P	P	Indurated sore in sulcus R. Marked general adenitis. Macular syphilide. Chronic headache.			

Explanation of the Tables.

"Unselected examples" are obtained by taking every second or tenth, or so forth case in the alphabetical card index.

"Selected examples" are instances which illustrate a condition well.

When no remark is made about selection of examples, those quoted are every instance of the condition.

W.R. = Wassermann reaction.
P = positive.
W.P. = weak positive.
V.W.P. = very weak positive.
D = doubtful.
0 = negative.
— = no observation.
C.S.F. = cerebro-spinal fluid.

THE EVIDENCE OF SYPHILIS OBTAINED.

Reactions and Conclusive Evidence of Syphilis

Previous Evidence of Syphilis.	*Probable Infection.* Date.	*Subsequent Evidence of Syphilis.* Effect of Treatment and Relapses.	Further W.R. Date.	Result.
	20.12.17	Sore healed		
W.R. 0, 21.12.17. In 1913 circumcised for subpreputial sores. Rash. Three injections of 606 in 1913 at Haslar and 33 injections of Hg.	Nov. 1917 1913	Sore healed		
Undoubted syphilis in 1915. One dose '914 15.2.15, and two years Hg. W.R. W.P. 15.2.15. P. 11.10.16.	Jan. 1915			
	Aug. 1917	Resolving. Relapse 24.1.18. Severe meningeal headache and diplopia. Men. gonorrhœa. coliur syphilis. 78o. Lymphocytosis on C.S.F. and W.R. 1+++	6. 2.18 18. 3.18	P. P.
Sore on penis 1916. No treatment.	Aug. 1916			—
W.R. P. 25.2.17. Two doses '914. Feb. Mar. 1917. Injections Hg. W.R. 0, 2.5.17.	Feb. 1917	Resolved		—
	6. 2.18	Lesions on palate;		
	May 1917	Abdominal Head [illegible]		—

EXPLANATION OF THE TABLES (*continued*).

The figure in the "Probable Infection" column denotes the number of weeks previous to the date of the W.R. examination.

The figures in the W.R. columns mean 1+++, 2+++, &c., and the proportion of the W.R. (in the case of 1+++) is a complete positive result with the quantities of fluid referred to, thus 1+++ denotes positive with the first two quantities and negative with the last two. Each quantity is 1/5 of the circulating fluid, the subject is 9 st., when using 0.5 c.c. of a 1 per cent. suspension of deprived sheeps' corpuscles in the first

tube = a strong reaction with complement & Syphilitic serum.
2nd " = a strong reaction with Normal serum.
3rd " = [illegible]
4th " = [illegible]
5th " = [illegible]

After the diagnostic W.R. and before the subsequent reactions, as above, the treatment was characterised unless there is a statement to the contrary.

TABLE I. *Unselected Examples of Men with Positive Wassermann*

Rec. No.	Date	Sex	Age	Clinical	Other Evidence of Syphilis: C.S.F. W.R.	
691	13.3.18	M		Acute psychosis of epileptoid character and found hanging. Marked pupillary inequality. Old Taboparesis and Peculiar syphilide.	S	0
269	7.12.17	F		Scars of acne in gelatine. Marked general eczema.	—	
289	7.12.17	F		Scars of acne on prepuce R. Macular syphilide. Mucous patches on tonsils and uvula.		
569	8.2.18	F	F	Scars on under surface of prepuce.	2	0
1057	28.7.17	F		Large healing Hunterian sore on under surface of prepuce Del.	—	
300	14.12.17	F		Scars of acne on glans Del. Copper stain of syphilitic type. Mucous patches on both tonsils.		
1521	1.7.18	F		Scar of ulcer on prepuce L. Follicular macular syphilide.	4	0
293	23.10.17	F	F	Multiple scars on glans and on prepuce. Macular-papular syphilide.	4	0
313	20.9.17	F	0	Scars on glans and lower surface of prepuce (probably not syphilitic). Retinitis, R. Scar L. Choroiditis.		
178	1.11.17	F		Indurated scar of sore on prepuce and on glans. Ulcer inside R. cheek.	—	
999	15.2.18	F		N.L.	2	0
981	12.4.18	F		Indurated scars on sulcus R. Mucous patches on buccal mucous membrane. Early gummata.	0	0
1342	14.6.18	F		Internal ear deafness.	2	0
1477	28.6.18	F		Scar of sore on prepuce L. Mucous patches on palate, posterior pillars of fauces and R. cheek.	0	0
51	13.8.17	F	F	Sore on upper lip R. Marked general eczema.		
9[illegible]	3.4.18	F	F	Two crusted papules on glans R. Ulcer on R. side of prepuce. Macular papular syphilide.	0	0
724	30.11.17	F		Multiple mucous patches, tonsils, uvula. Ulcers left cheek. Papular syphilide.	—	

Reactions and Conclusive Evidence of Syphilis (continued).

Previous Evidence of Syphilis.	*Probable Infection.* Date.	*Subsequent Evidence of Syphilis.* Effect of Treatment and Relapses.	Further W.R. Date. Result.
	4.10.17	Resolved	10. 5.18 0
Sores on penis Nov. 1917. Treated with one dose '914'. W.R. P.	Aug. 1917		Jan. 1918 0
	Nov. 1916	Resolved.	12. 7.18 V.W.P.
—	26.12.17	Healed.	— —
One dose of Galyl 5 7.17.	21. 6.17	Healed.	17. 8.17 P 13. 9.17 0 12. 4.18 0 1. 7.18 W P.
—	July 1917	No treatment.	
—	Deemed.	Resolved.	— —
—	July 1917	Healed.	28.11.17 0 4. 1.18 P 18. 1.18 0 8. 2.18 P
—	Sept. 1916	Sores healed. Eyes unchanged.	2. 1.18 P
One dose of Galyl, 7.11.17.	Sept. 1917	Healed	7.12.17 W P.
Sore on penis in Nov. 1916. Treated with one dose '606'. W.R. P. Rash in Nov. 1917. Hg injections.	Sept. 1916		— —
Sore on penis in 1909. Treated with Hg.	May 1909	Improved	— —
Sore on penis in 1916. Three doses of Galyl in Nov. 1917. Four injections of Hg.	Oct. 1916 Oct. 1917	No change Resolved.	— — — —
—	?	Healed	5. 9.17 V W P. 1. 3.18 V W P. 15. 3.18 0 7. 6.18 0
—	Oct. 1917	Resolved.	— —
—	1. 9.17	Resolved	10. 5.18 0 12. 7.18 0

TABLE I. *Unselected Examples of Men with Positive Wassermann*

Lab. No.	W.R. Date.	Extract.	S. prod.	Present Evidence of Syphilis. Clinical	S. & L. Cells	W.R.	Extr.
676	17. 9.17	F	F	Scales on pubes			
669	22. 2.18	F	F	Healing sore on glans Dec. L.	3	0	
728	12.12.17	F	—	Early 2° rashes	2	0	
977	22. 2.18	F	—	Scars of sores on prepuce L.	0	+	
905	20. 3.18	I		Scars of sores on frenum & prepuce L. Palm of left hand pigmented.	0	+°	
870	22. 3.18	F	F	Multiple scars on inner surface of prepuce. Dec. Marked general adenitis. Mucous patches on tongue. Lues. Circumcision not healing. Secondary syphilis.	22	0	
1144	3. 5.18	F		Indurated sore on inner of prepuce. Dec. Eczema on glans Ind. Marked general adenitis. Mucous patches. Syphilis.	3	+	
624	15. 2.18	F	F	Indurated sore on inner surface of prepuce. Dec.	3	0	
33	17.10.17	F		Nil.			
1114	3. 5.18	I	F	Large scar on frenum & prepuce L.	4	0	
566	1. 2.18	F		Scars of sores on penis V	800	1000	F
806	14. 6.18	F		N	0	0	
1117	3. 5.18	F		Scars of multiple sores on inner surface of prepuce. Papulo-squamous syphilide. Marked pediculosis. Lues. Circumcision.	0	0	
133	18. 1.18	F	F	Scars on penis L.			
233	2.11.17	I	F	Lues. Scars of sores. Mucous patches. Dirty. Pediculosis. Syphilis.			—
867	8. 2.18	I		Scars of old sores on penis. Marked general adenitis. Secondary & palmar and R. rashes. Healing syphilitic sore on frenum.	4	0	
87	30. 8.17	I		Scars of frenum. Papulo-squamous syphilide.			
580	8. 3.18	I		Circum. superficial gran.	12	0	F

Reactions and Conclusive Evidence of Syphilis (continued).

Previous Evidence of Syphilis.	*Probable Infection.* Date.	*Subsequent Evidence of Syphilis.* Effect of Treatment and Relapses.	Further W.R. Date.	Result.
	7. 9.17	Healed	25. 1.18	W.P.
			17. 5.18	0
			16. 8.18	0
	24.11.17	Healed.		
Sore on penis, rash, and sore throat in 1909. Treated with Hg. for 3 years.	1909	Improved		–
Sore on penis, rash, and sore throat. Black wash to sore.	Oct. 1917		14. 6.18	0
Sore on body of penis L. Sore throat.	1906	Resolved.	—	—
	Oct. 1917	Resolved	—	—
	1. 4.18	Resolved.	—	—
	25.12.17	Healed.	—	–
Sore on penis, and rash	Dec. 1916	—	4. 1.18	P
			22. 2.18	P
			10. 5.18	0
	3. 3.18	Healed	9. 8.18	0
Sore on penis at end of 1917, and rash. Treated with one dose of Ovdyl.	Sept. 1917	—	—	–
Rash on body. Treated with 6 injections of Ovdyl in 1916-17 and 27 injections of Hg.	Oct. 1916	—	—	—
Two doses of Ovdyl and Hg.	2. 2.18	Resolved.	—	–
	2.11.17		19. 4.18	0
			12. 7.18	0
	3.11.17	Healed [illegible]	26. 1.18	0
[illegible]	May 1903			–
	July 1917	[illegible]	26. 9.17	P
			17.10.17	0
[illegible]	1893	[illegible]	6. 9.18	P

TABLE I. *Unselected Examples of Men with Positive Wassermann*

Ref. No.	W. R. Date	Result	Type	Clinical Features of Syphilis. Other	C. S. F. Cells	C. S. F. W. R.	C. S. F. Lues
708	29 1 18	+		No	83	++	
6	31 1 17	+	—	Large central perforation of soft palate. Gummata tongue, cervical gl. of tongue	—		—
671	25 1 18	+	0	Manifest syphilis			
1459	1. 6 17	+	—	Scars of old gums on tragus and legs	—	—	—
980	12. 4 18	+		No scars. Lesions in penis. Mucous patches on palate, tonsils and buccal mucosa. Scrotal glands. Condylomata ani. Chancre chancre. Disseminated papules on abdo.	3	3	
964	12 4 18	+		Scars of gums at sides L. Scars of old rash on body	1	1	+
736	8 3 18	+		Dry scales	183	0	
720	22 2 18	+		Gummatous syphilodermy rupia of groin and thigh L.	4	0	—
464	25 1 18	+	+	Indurated ulcer on corona gl. L. of prepuce. Marked inguinal adenitis		—	—
1519	5. 7.18	+		Two healing ulcers on glans, scarred. Healing ulcer on prepuce. Several superficial scars on abdomen	20	0	—
797	6 3 18	+		Many fresh papular syphilide	132	0	
393	2 1.18	+	0	Indurated sore on prepuce and scar of prepuce. Macular syphilide.	—	—	—
6	18.10 17	+		Scars of gums on lateral parts. Ulceration of L. tonsil	—	—	—
1450	21 6 17	+		Scar on edge of prepuce. E. V. Ulceration of gum, palate and tonsils	0	0	—
143	10 11.17	+		Scar on penis. Syphilide.	—	—	—
992	15 3.18	+	+	Large ulcer on prepuce L.	—	—	—
791	1 3 18	+	+	Scar at frenum and on prepuce E.	2	0	
874	1 3 18	+	0	Two crushed papules on under surface of prepuce. Macular syphilide	28	0	—
447	18 1 18	+		Three scars on glans E. Marked general adenitis. Macular papular syphilide.	—	—	—
1497	29 4 18	+		Scars of gums at back of mouth. Scars left knee. Mac. and p. syphilide.	48	0000	+
1121	3 3 18	+	+	Indurated ulcer on corona L.	4	0	
88	24.10 17	+		Scars of ulcers on legs. General adenitis		—	—

Reactions and Conclusive Evidence of Syphilis (continued).

Previous Evidence of Syphilis.	*Probable Infection.* Date.	*Subsequent Evidence of Syphilis.* Effect of Treatment and Relapses.	Further W.R. Date.	Result
Sore on penis, and rash in 1903.	1903			
	? 1900	Healed.	9. 6.17	P
Three doses of Galyl in 1917.	Sept. 1916	Resolved.		
Three injections of [illegible] in 1916.	1901 or 1902		6. 7.17	P
			31. 5.18	P
	?	Resolved.		
Sore on penis, rash and sore throat in 1904.	1904			–
Sore on penis, and rash. Treated with four injections of Galyl.	Jan. 1917	Recovered.	4. 4.18	V.W.P.
			21. 6.18	0
	Denied.	Healed.		–
	Nov. 1917 to Jan. 1918	Healed.		
Sore on penis, 1916. Circumcised. No treatment.	? 1916 or 20. 3.18	Healed. Resolved.		
Sore on penis, 1913.	Oct. 1913	–	–	–
	Nov. 1917	Healed. Recovered.	17. 5.18	P
			30. 8.18	0
Two doses of Galyl, Oct. 1917.	Sept. 1917	Ic. tonsil. Healed with much scarring.	18. 4.18	0
			17. 5.18	0
			9. 8. 8	0
Discharge from penis 1902.	1902	Healed.		–
	1897	Recovered.		–
	Dec. 1917	Healed.	–	–
	11. 2.18	Healed.		–
	1. 3.18	Resolved.		–
	10.11.17	Healed. Recovering.		–
	Mar. 1918	Resolved.	19. 7.18	0
One dose of Galyl, Apr. 1918.	26. 2.18	Healed.	–	–
–	1907		19. 4.18	P

TABLE I. *Unselected Examples of Men with Positive Wassermann.*

Hos. No.	W.R. Date	Result	S. and	Clinical Evidences of Syphilis	C.S.F. Cells	W.R.	Date
466	22 2 18	P.	P.	Scl. unsupported scars of [illegible]	4	0	
446	1 2 18	W.P.		Irregular pupil of R. side of patient. Otherwise good nervous examination of R. clinic			
451	10 9 17	P.	P.	Extensive unsupported scars of [illegible]			
1092	19 1 18	P.		Scars of Hutchinsonian type by [illegible] R. Del. Marked general sclerosis. Muscles [illegible]	2	0	
1839	14 6 17	P.		Scars on penis. Syphilide.			
292	24 10 17	P.	P.	Scars on [illegible]	3	0	
1464	21 6 18	P.	P.	Large [illegible] Extensive unsupported syphilide	2	0	
899	29 3 18	P.	P.	Hutchinson [illegible] scars [illegible] R. Del.	0	0	
894	30 3 18.	P.		Scars of unsupported type R. Muscular [illegible]			
1121	3 4 18	P.	0	Large [illegible] Hyperplasia and thickening of [illegible]	1	0	
702	9 9 17	P.	P.	Scars on [illegible] Del. I.			
852	2 3 18	P.		Pupils of [illegible] R.V. Choroiditis [illegible]	0	0	
7[illegible]	1 3 18	P.	P.	Hutchinson [illegible]	0	0	
889	29 3 18	P.	0	Eye [illegible]	2	0	
1096	5 4 18	P.		Scars of [illegible]	0	4000	3
320	21 5 17	P.		Scars of [illegible]			
641	4 2 18	P.		[illegible]			
871	1 4 18	P.	P.	[illegible]	0	0	
137	[illegible] 18	P.		[illegible]	2	0	

Reactions and Conclusive Evidence of Syphilis (continued).

Previous Evidence of Syphilis.	*Probable Infection* Date.	*Subsequent Evidence of Syphilis.* Effect of Treatment and Relapses	Further W.R. Date.	Result
–	15.12.17	Healed.	–	–
Four doses '914', Jan. 1918.	Denied	Healed.	–	–
–	Aug. 1917	Healed. Resolved.	11. 1.18	0
			5. 4.18	0
S. pallidum present.	10. 1.18	Resolving.	–	
–	17. 5.17	Healed. Resolved	6. 7.17	P
			3. 8.17	P
			21. 9.17	0
			8. 8.18	D
			6. 9.18	0
	Denied	Healed.	25. 1.18	0
–	10. 4.18	Healed. Resolved.	–	–
–	22. 2.18	Healed.	21. 6.18	0
Sore on prepuce.	15. 7.17	Resolved.	2.12.17	0
			22. 2.18	V.W.P.
			9. 8.18	0
None.	Denied	Healed. Resolved.	–	–
–	June 1917	Healed.	8. 2.18	0
			15. 3.18	0
	Denied	Resolved.	9. 8.18	0
	Jan. 1918	Healed.	–	–
	1.12.17	Healed. Resolving.	–	–
Sore on penis.	14.11.17	No change.	–	–
	0.0. 1917	Resolved.	–	–
	Denied		–	–
Treated with two injections of Hg.	20.12.17	Healed. Resolved.	–	–
–	9. 4.18	–	–	–

TABLE 1. *Unselected Examples of Men with Positive Wassermann*

Ref. No.	W.R. Date.	W.R. Result	*Present Indications of Syphilis.* S. pain.	Clinical	C.S.F. Cells	C.S.F. W.R.	C.S.F. Lymph.
741	8. 3.18	P	P	Septic sore at fracture.	2	0	—
51	29.10.17	P	—	Clinically lg. L.	—	—	—
309	11. 1.18	P	P	Healing sore in sulcus L.			
1798	14. 2.17	P	P	Acquired phimosis. Excoriations. Subpuberal scars. Circumcised.	—	—	—
1149	26. 4.18	P	—	R. tonsil scarred.	—	0	—
866	22. 3.18	P	—	Indurated almost healed sore on sulcus Dsl. R. Condylomata ani. Tonsil ulcerated.	2	0	
918	29. 3.18	P	P	Scabbed over moist papular. mucous. Inside cylinder L.	0	0	
1324	17. 5.18	P	—	Nil.	Nil	0	—
232	30.11.17	P	0	Oval healing ulcer R. thumb. No history of injury. Sore in sulcus. Macular papular syphilide.			
914	22. 3.18	P		Early Glossitis.	2	0	

TABLE 2. *Unselected Examples of Men with Positive Wassermann for Local*

Ref. No.	W.R. Date.	W.R. Result	*Present Indications of Syphilis.* S. pain.	Clinical	C.S.F. Cells	C.S.F. W.R.	C.S.F. Lymph.
678	22. 2.18	P	—	Scar of old sore on body of penis Dsl., also moist mucous.	2	0	—
1356	10. 5.18	P	—	Scar of sore on under surface of prepuce, R.	0	0	—
998	12. 4.18	P	—	Phimosis. Incubation of under surface of prepuce. Large syphilis sore under surface of prepuce, V.R.	2	0	—

Reactions and Conclusive Evidence of Syphilis (continued).

Previous Evidence of Syphilis.	*Probable Infection.* Date.	*Subsequent Evidence of Syphilis.* Effect of Treatment and Relapses.	Further W.R. Date.	Result.
	25.12.17	Healed.		
Sept. 1915 W.R. P. Had two doses of "606" in Jan. and Feb. 1916. Refused treatment before. W.R. 0, 5.11.16.	June 1915	Healed.	8. 3.18	P
Two doses of Galyl in Dec. 1917.	20.10.17	Healed.	17. 5.18	0
	1. 1.17	Healed.	5. 5.17 1. 9.17 9. 8.18	P 0 0
Had three doses of Galyl in July and Aug. 1917, and 18 injections of Hg. Sore on penis, rash, and sore throat.	14. 4.17	—	—	—
S. pallidum P, 6.1.18.	15.11.17	Healed.	9. 8.18	0
	28. 1.18	Healed. Resolved		
Gonorrhœa in 1912 followed by sore on penis and sore throat. Hg for two years.	1912			
	3.10.17	Healed. Resolved.	22. 3.18 7. 6.18	0 0
Circumcised for subpreputial sore. Lump in L. groin, 1908. Recent tonsilitis. Hg pills for 18 months from 1908.	1908	Tongue resolved		

Reactions who had been Diagnosed as Syphilis and Treated Lesions Outside.

Previous Evidence of Syphilis	*Probable Infection.* Date	*Subsequent Evidence of Syphilis.* Effect of Treatment and Relapses.	Further W.R. Date.	Result.
Sore on body of penis 1896, and inguinal mucous in 1911. One dose of Galyl in Sept. 1917 and continuous Hg	1896 or Jan. 1911	—	—	—
Sore on penis, Dec. 1917. "Black Wash" and Hg pills for three months.	Nov. 1917	—	9. 8.18	0
Hg pills and local antiseptics	Feb. 1918	Healed.		

TABLE 2. *Unselected Examples of Men with Positive Wassermann for Local Lesions*

Ref. No.	W.R. Date	Result	Syphilis	Present Evidence of Syphilis: Clinical	C.S.F. Cells	C.S.F. W.R.	Previous Treatment
132	2.11.17	P		Scar on scrotum	2	0	
1162	19. 4.18	P		General edematous	3	0	
1091	3. 5.18	W.P	0	Pigmented scar of sore (1916) on body of penis. Ind. R. Indurated sore on sulcus R.	0	0	
153	9.11.17	P		Sore on under surface of prepuce			
170	6. 7.17	P		Indolent soft sore on R. margin of prepuce			
1198	3. 5.18	P		Scar of sore on glans L. (1909). Syphilodermid on trunk and penis extending on to scrotum	4	0	
374	11. 8.18	P		Scar of sore on prepuce			
667	6. 2.18	P		Scar of sore on body of penis	2	0	
700	9. 9.17	P		Scar of sore on penis V			
1078	3. 5.18	P		Obliterations of prepuce. Healing ulcer on sulcus. Ind. L.	4	0	
118	6.10.17	W.P		Scars of multiple recent sores in sulcus			
191	19.11.17	P		Healing sore at frenum			
1065	19. 4.18	P		Scar of sore on body of penis. R. Scar of sore on glans	4	0	
208	3. 5.17	P		General edematous			
48	27.10.17	P		Sore on prepuce			
945	23. 3.18	P		Indurated scar of recent sore on sulcus R.	2	0	
369	23.11.17	P		Scar of plaque sore under prepuce. Ind.			

Reactions who had been Diagnosed as Syphilis and Treated Outside (continued).

Previous Evidence of Syphilis	*Probable Injection Date*	*Subsequent Evidence of Syphilis.* Effect of Treatment and Relapse	Further W.R. Date	Result
Sore on penis in 1910, treated with Hg for three months.	1910			
Sore on penis, Feb. 1918. Treated with one dose of Galyl and five injections of Hg.	28. 1.18		6. 7.18	0
Sore on penis in July 1916, treated with one dose of Galyl and three injections of Hg.	1916 or last three months.	Healed		
One dose of Galyl nine days ago.	10. 9.17	Healed		
One dose of Galyl, 1.7.17, and Hg.	5. 5.17	Healed	11. 8.17 13. 9.17 12. 3.18	0 0 0
Two doses of "606" in Jan. 1912 for sore on penis. Also had a sore in 1909.	1909 or 1912	Healed		
In July–Aug. 1916 two doses of "606".	June 1916			
Sore treated with one dose of Galyl and one injection of Hg.	9.12.17			
Sore on penis treated with three doses of Galyl and Hg injections.	26. 6.15			
Balanitis, phimosis. Prepuce slit, 10.4.18. One dose of Galyl same day.	2. 3.18	Healed		
Sores in sulcus. Two doses of Galyl in Oct. 1917.	Sept. 1917		8. 2.18	0
One dose of Galyl, 26.10.17.	28. 9.17	Healed	8. 2.18	0
Sores on body of penis ten years ago. Sore in Feb. 1918 treated with eight injections of Hg.	Jan. 1918 or 1908			
Sore on penis and bubo. One dose of "606" in Apr. 1917.	Dec. 1916		5.12.17	0
Three doses "914" in Oct. 1917.	Aug. 1917	Healed	25. 1.18	0
Lot. Negra to sore. Two injections of Hg.	19. 2.18			
Sore on penis, one dose of Galyl Dec. 1917.	0.4. 1917			

TABLE 3. *Men with Positive Wassermann Reactions who were*

Ref. No.	W.R. Date	W.R. Result	S. pall.	Present Evidence of Syphilis. Clinical	C.S.F. Cells	C.S.F. W.R.	C.S.F. Eyes
1069	11 4.18	P		Superficial warts	36	o	
1130	3 5.18	W.P.		Indurated scars of small ulcers in sulcus and on under surface of prepuce	176	o	P.
1139	3 5.18	P	o	Indurated ulcer on under surface of prepuce. Dsd	18	4	
1170	3 5.18	P		Faint scar in sulcus R.	o	o	P.
1261	17 5.18	P		Phimosis	18	o	
1223	17 5.18	P		Indurated scar of ulcer in sulcus Dsd R. Scar of R. of frenulum	32	o	
947	29 3.18	P		Papules R. and L. coronal sulcus. No scar on penis	14		
1036	19 7.18	P		Nil.	14	4	
620	8 2.18	P		Scar of recent sore, body of penis L. Scar of old sore on glans 3/4 R. of meatus	128	1400	
1163	3 5.18	P		Nil.	10	o	
1064	19 4.18	P		Headaches for 4 months. Insomnia. Memory for recent events bad	16	o	P.
1159	3 5.18	P		Scar of ulcer on prepuce Dsd	2	4	
1400	28 6.18	P		Nil. No scar on penis	30	o	
1360	7 6.18	P		Scar of sore on prepuce Dsd. (1917). Phimosis, balanitis, excoriations on edge of prepuce	42	o	
1501	14 6.18	P		Nil. Gonorrhœa	2	o	P.
1471	31 5.18	P		Excoriating ulcer (a syl.) on R.	56	o	

TABLE 4. *Men with Positive Wassermann Reactions who had as Syphilis and Treated*

Ref. No.	W.R. Date	W.R. Result	S. pall.	Present Evidence of Syphilis. Clinical	C.S.F. Cells	C.S.F. W.R.	C.S.F. Eyes
1390	20 5.18	P		Scarred papules in coronal sulcus on glans and on under surface of prepuce	8	o	
1137	26 4.18	P		Dartrous and attached to meatus anteriorly. Sore Sept. 1917.	92	1400	
1387	7 6.18	P		Scars of two recent sores on body of penis R.	22	o	o
1084	20 4.18	P		Nil	170	1400	P.
1471	21 6.18	P		Scar of flat ulcer on glans 1911	292	0000	

shown to have Disease of the Central Nervous System only.

Previous Evidence of Syphilis.	*Probable Infection.* Date.	*Subsequent Evidence of Syphilis.* Effect of Treatment and Relapses.	Further W.R. Date.	Result
Local antiseptics to sores *S. pallidum* 0.	20. 3.18 Dec. 1917	Healed	10. 5.18	0
Local antiseptics to ulcer. Sore on penis in 1899.	? ? 1899 Apr. 1918 4. 3.18	Healed		
	28. 1.18			
Gonorrhœa 1903 Sore on penis in 1913, another in Aug. 1917	? 1903 ? 1913 or Aug. 1917			
Swellings at anus (? Condylomata.)	?.12.17 Denied		?.?.18	0
Sore on penis, 1914. Sore on penis, 1915. Sore on penis twelve months ago.	1914 Mar. 1915 1917 or 1. 5.18	Healed.		
Gonorrhœa Feb. 1917 Local antiseptics to sore	? Feb. 1917 20. 3.18	Healed		

Disease of the Central Nervous System and had been Diagnosed for Local Lesions Outside.

Previous Evidence of Syphilis.	*Probable Infection.* Date.	*Subsequent Evidence of Syphilis.* Effect of Treatment and Relapses.	Further W.R. Date.	Result
Sore on penis Sept. 1916. One dose of Galyl in Apr. 1917. Six doses of '914' Apr. 1918.	? Sept. 1916			
Three doses of Galyl in Feb.-Mar. 1918. Sore on penis, 1907.	1907	Improved.		
Sores treated with two doses of Galyl.	? 3.18			
Sore on penis, 1914. Three doses of Galyl in 1915. Three years Hg.	Sept. 1914			
Five doses of Galyl May 1918, and inunctions of Hg.	14. 2.18			

TABLE 5. *Unselected Examples of Men with Positive Wassermann*

Hosp. No.	W.R. Date	Result	No. of sores	Clinical	Present Incidence of Syphilis: Cases	W.R.	Date
973	12. 4.18	P		No sores. Gland. Gummatous adenitis. Doubtful history	2	3	
514	8. 3.18	P	0	Irregular ulcer at root of penis. Del. Indurated bubo L. groin. Gen. adenitis			
391	1. 3.18	P	—	Indurated scar of recent sore on edge of prepuce L.			
811	19. 7.17	P		Sore on penis			
28	30. 8.17	P	0	Sores on inner surface of prepuce			
486	21.12.17	P		Nil.			
130	21. 7.17	P		Scar on inner surface of prepuce			
59	19.10.17	P		Healed sore on prepuce.			
5	9.10.17	P	0	Sore on body of penis.			
260	29.10.17	P		Nil	2	0	
358	21.12.17	P		No sore on penis. Bubo			
121	23.11.17	P		Scar of old sore on prepuce. Scar of recent sore on scrotum			
76	31.10.17	P		Scar of scratching. Scars of ulcers on legs			
78	2.11.17	P	—	Gonorrhœa			
1049	26. 4.18	P		Scar of sore at meatus	1	0	
1306	22. 6.17	P	—	Scar of sore on scrotum. Scar of recent bubo	—	—	—
884	8. 6.17	P		Scar of sore on corona			
1442	21. 6.18	P		Two septic ulcers at fore-fraenum. Scar of old sore on glans R. General adenitis			
893	26. 5.17	P		Recently circumcised			
1315	2.11.17	P	—	Scar of old sore on prepuce. Gonorrhœa	—	—	—

Reactions who had a Similar Reaction Previously or Subsequently.

Previous Evidence of Syphilis.	*Probable Infection.* Date	*Subsequent Evidence of Syphilis.* Effect of Treatment and Relapses.	Further W.R. Date.	Result
24.11.17 W.R. P.	?	—	5. 7.18	0
—	Feb. 1918	Healed	21. 6.18	P
Sore on penis. Local antiseptics. W.R. V.W.P. 22.2.18	Dec. 1917	—	12. 7.18	0
	26. 6.17	Healed.	24. 8.17	P
			30. 9.17	0
			1. 3.18	0
			31. 5.18	0
Local antiseptics	? May 1917	Healed.	11. 9.17	P
			23.10.17	0
	1908		31. 5.18	P
	? 1912	W.R. relapsed in Mar 1918.	16.11.17	0
			1. 3.18	P
	27. 9.17		1. 2.18	P
	Aug. 1917	Healed	26. 4.18	P
Sore on penis.	1906	—	1. 2.18	P
			26. 4.18	P
W.R. P., 8.12.17.	Oct. 1917	—	1. 2.18 V.W.P.	
Sore on penis, 1913 W.R. P., 1.11.17	? 1913 or Oct. 1917	—		
	May 1918	—	22. 3.18	P
	1912	—	14. 2.18	P
Sore on penis, 1903 W.R. P., Apr. 1918.	1903	—		
Sore on penis, Apr. 1917	Feb. or Mar. 1917	—	28. 7.17	P
			10. 5.18	0
Sore on penis	Apr. 1916	—	13. 7.17	P
			28. 7.17 V.W.P.	
			17. 8.17	0
			30.11.17	0
			8. 3.18	0
			7. 6.18	0
			30. 8.18	0
Gonorrhœa. Sore on penis, 1912. W.R. P. 2.6.18	1912 or 4. 4.18	Healed		
Subperiosteal node on tibia, 9.4.17	20. 3.17	—	14. 9.17	P
			21.12.17	0
			22. 4.18	0
			19. 7.18	0
Penile sore	1907	—	17. 4.18	P

TABLE 6. *Men with Positive Wassermann Reactions who were had Positive Wassermann Reactions*

Hist. No.	W.R. Date	Result	Symptoms	Clinical	Syphilis C.S.F. Cells	W.R.	Treat.
1003	28. 4.18	+	Nil.		14	∞	
987	8. 2.18	P	Nil.		14	—	0
1281	17. 7.18	P	Scars of [illegible]		42	+	P
943	8. 2.18	P	[illegible]		140	4000	+

TABLE 7. *Men with Positive Wassermann Reactions who had been also Positive Reactions*

Hist. No.	W.R. Date	Result	Symptoms	Clinical	Syphilis C.S.F. Cells	W.R.	Treat.
67	29. 8.17	P	Scars of [illegible]				
1105	26. 4.18	P	Scars of [illegible]		0	0	
1302	19. 9.17	P	Nil.		0	0	
769	20.10.17	P	Scars of [illegible]				
302	7.12.17	P	Nil.				
423	18. 1.18	P	Healing [illegible]				
1189	14. 6.18	P	Nil.		0	0	
891	26. 4.17	P	Nil.				
452	29. 9.17	W.P	Nil.				
983	4. 4.18	P	Nil.		0	0	
1041	28. 6.18	V.W.P	Scars of [illegible]		4	0	—

shown to have Disease of the Central Nervous System and who Previously or Subsequently.

Previous Evidence of Syphilis.	*Probable Infection Date*	*Subsequent Evidence of Syphilis.* Effect of Treatment and Relapses.	Further Date.	W.R. Result.
Sore on glans, Jan. 1918. W.R. P., 16.4.18.	? Nov. 1917	—	30. 7.18	P
Gonorrhœa 1914.	Denied	—	12. 4.18	V.W.P.
	10. 3.18	—	26. 7.18	P
Sore on penis	May 1917	—	7. 6.18	P

Diagnosed as Syphilis and Treated for Local Lesions Outside and Previously or Subsequently.

Previous Evidence of Syphilis	*Probable Infection Date*	*Subsequent Evidence of Syphilis.* Effect of Treatment and Relapses.	Further Date.	W.R. Result.
Sore on scrotum in 1915. Had two doses of Galyl in June–July 1917.	Dec. 1914	—	23.10.17	P
14.12.17, W.R. P. One dose of Galyl and 18 injections of Hg. 5.3.18 W.R. P.	2. 8.17	—	26. 7.18	0
Sore on penis in 1916, treated with Hg injections.	16. 7.16	—	21.12.17 10. 5.18	P P
Sore on under surface of prepuce treated with two doses of Galyl and Hg.	Mar. 1916	—	14. 2.18 17. 5.18 9. 8.18	P 0 0
Had four doses of Galyl from Dec. 1916 to Jan. 1917 and Hg irregularly.	Nov. 1916		22.12.17	P
In Dec. 1917 three doses of '606.' W.R. P.	Oct. 1917	Healed.		—
Balanitis. W.R. P 28.6.18. Treated with one dose of Galyl	26. 4.18			
Sore on penis about 14. 2.17. Treated with one dose of Galyl.	?	—	29. 7.17 11. 8.17 22. 3.18	P 0 V.W.P.
July 1917 sore on penis, treated with three doses of Galyl.	May 1917	—	11. 1.18	V.W.P.
Sore on penis, 1907, treated with one dose of '606' in 1909 and three years Hg. W.R. P., 19.2.18.	1907	—		—
Sore on penis in 1913 and Apr. 1918, the latter treated with one dose of Galyl and Hg. W.R. P. 10.4.18.	1913 or 1918	—	19. 7.18	W.P.

TABLE 7. *Men with Positive Wassermann Reactions who had been and who, further, had Positive Reactions*

Del. No.	W.R. Date	Result	S. & O.	Clinical	Duration of Syphilis. C.S.F. Date	C.S.F. W.R.	C.S.F. Result
743	24/10/17	P		Scars on Penis.			
899	23/11/17	P		Scars on prepuce (? syphilis). Lymphadenopathy. Gonorrhœa.			
181	18/11/17	W.P.		Old history of syphilis. Supra-pubical scars.			
1182	3/5/18	P	0	Scars of sores on body of penis. Del. 4/11. Has had two injections in region (1911). Deep healing ulcer on corona and L. margin. W.R. nearly negative to R. of hæmatin. Two patches of small discoloration on L. side of penis.	0	0	
298	11/2/18	V.W.P.		Extensive scars of sores on prepuce. Del.	0	0	
1402	28/6/18	P	0	Extensive scars on body of penis. Scar on R. testicle where an ulcer had been. Hyperæmia of L. testicle. Lymph glands in groin enlarged.	4	0	
1120	3/5/18	V.W.P.		Nil.	0	0	
981	18/4/17	P		[illegible]			
1203	14/6/18	P		Scars of sores on body of prepuce. Deep ulcer on Del. Corona and frenum.			
2388	31/8/17	P		Scars on penis. Scar on R. testicle. Del. [illegible]			
1443	2/10/1	P		Nil.	2	0	—
1606	19/1/18	W.P.		[illegible] Abdominal scars.	40	0	

Diagnosed as Syphilis and Treated for Local Lesions Outside Previously or Subsequently (continued)

Previous Evidence of Syphilis	*Probable Infection Date*	*Subsequent Evidence of Syphilis*			
		Effect of Treatment and Relapses		Further W.R. Date	Result
Sore on penis, 1914. Treated with two doses of 606 in 1914	Feb. 1914			24.11.17	P
Sores on penis, 1907. Treated by Hg for four months.	1907	—		1. 3.18	P
W.R. 0, 6.11.17. One dose of 606, 12.11.17.	Sept. 1917	Healed		8. 2.18	P
Sore on penis 1914, and rash on pubis. Two doses of '914' Jan. 1915	'1914' — 4. 1.18	Healed.		9. 8.18	W.P.
Sore on penis, 1916. Three doses of Gold in June and July 1916. Two doses of '914' in Nov. 1917. W.R. P. Apr. and Oct. 1917	Feb. 1916	—		8. 2.18 22. 2.18 10. 4.18	0 I P
W.R. 0, 14.6.18, and W.P. 21.6.18. Black Wash and Hg pills	12. 4.18	Healed		—	—
Gonorrhœa in Dec. 1914. Sixth chafe of penis in Feb. 1917. W.R. P. Nov. 1917. Three doses of Gold	Feb. 1917	—		—	—
W.R. P. May and June 1916. Had three doses of 606 and Hg	May 1916	Healed		17.10.17 18. 1.18 17. 3.18	0 0 0
Sore on penis, Mar. 1917. Treated with six injections of '914'. W.R. P. 1917.	2. 4.18				
Sore on glans. Treated with four doses of Gold in 1917 and ten months of Hg	Oct. 1916			11. 9.17 13. 3.18	P 0
Papular sore. Six doses '914' Jan.–Aug. 1917. W.P. P. on 7.2.17, 28.4.17, 1.6.17. W.R. 0, 14.7.17	Nov. 1916			8. 4.18	I
Pustular sore. W.R. P. 26.4.17. Hg pills used Dec. 1917	Nov. 1917			10. 7.18	0

TABLE 8.

Men with Positive Wassermann Reactions who were shown to have, and Treated for, Local Lesions Only, and who have

Ref. No.	W.R. Date.	Result.	Present Evidence of Syphilis. S. and L.	Clinical	C.S.F. Cells	C.S.F. W.R.	Blood
59	2.18	P.		Nil	307	4440	1
664	22. 2.18	P.	—	Scar of penis or foreskin	11	0	
1177	3. 5.18	P.	—	Scars of papules on glans	182	4000	—

TABLE 9. *Unselected Examples of Men with Positive Wassermann*

Ref. No.	W.R. Date.	Result.	Present Evidence of Syphilis. S. and L.	Clinical	C.S.F. Cells	C.S.F. W.R.	C.S.F. Colloid
52	16.10.17	P.	—	Suspected history	—	—	—
1142	3. 5.18	P.		General adenitis. Gonorrhœa.	0	0	
429	9. 2.18	P.		Adenitis of right groin and axilla. Gonorrhœa.			
764	10. 8.17.	P.		Interstitial scars. Recent rubeola. Gonorrhœa. Incipient adenitis.			
1284	3. 7.18.	P.		Scars on sites of previous L. Gonorrhœa in remote. Gonorrhœa.	2	0	
1150	3. 5.18.	P.		Gonorrhœa. Epididymitis on R.	4	0	
1156	3. 5.18.	P.		Bleeding sore in L. and hæmorrhoids. Rubella.	2	0	
170	13.10.17.	P.	+	Scars on foreskin and on Scar of old sore on body. Scars of papules. General adenitis.			
867	17. 1.18.	P.	+	Scars on penis. General adenitis.			
1502	13. 8.18.	P.	0	Suspected. Alive 10 years. 1 year. General adenitis.			
488	12. 4.18.	P.		Old papular eruption on penis. One large scar on body of penis. V. General adenitis.	0		0
330	6.11.17.	P.	0	Scars on penis. Scars of papules. Psoriasis. Rubella. General adenitis.			
348	7. 1.18.	P.	0	Chronic sores on glans. R. General adenitis. Gonorrhœa.			

Disease of the Central Nervous System, who had been Diagnosed Positive Wassermann Reactions Previously or Subsequently.

Previous Evidence of Syphilis.	*Present Inspection* Date	*Subsequent Evidence of Syphilis.* Effect of Treatment and Relapses	*Subsequent Evidence of Syphilis.* Further W.R. Date	Result
Sore on penis in 1916 treated with two doses of Galyl and one of '914'. W.R. P., 4.6.17.	May 1916	—	31. 5.18	0
			16. 8.18	0
Sore on penis, W.R. P., Oct. 1916. One dose of Galyl Nov. 1916, and Hg ever since.	13. 7.16			
Sore on penis, 1916. Hg for three months.	May 1916	—	9. 8.18	P

Reactions in whom no Direct Evidence of Syphilis was found.

Previous Evidence of Syphilis	*Present Inspection* Date	*Subsequent Evidence of Syphilis.* Effect of Treatment and Relapses	*Subsequent Evidence of Syphilis.* Further W.R. Date	Result
Sore on penis in May 1917.	15. 4.17	—	—	—
'Chancroid' in 1915.	July 1915	—	—	—
	?	—	—	—
	June 1917	Healed	8. 3.18	0
Black Wash to sore W.R. 0, 16.5.18	30. 4.18	Healed	16. 8.18	0
	Denied			
	28. 3.18	Healed.		
Sore on body of penis in 1912	1912 or 1.10.17	Healed.		
W.R. 0 on 2.5.17. Local antiseptics	29. 2.17	Healed	22. 7.17	0
			28. 1.18	0
Ammoniated mercury	15. 8.17.	Healed	26. 7.18	0
	5. 2.18	Denied		
	1.10.17	Healed	1. 4.18	0
			7.18	0
Local antiseptics	1.11.17	Healed	3. 5.18	0

TABLE 9.

Unselected Examples of Men with Positive Wassermann Reactions

B.S. No.	W.R. Date.	W.R. Result	Symptoms (if any)	Clinical condition of Nervous System	C.S.F. Cells	C.S.F. W.R.	C.S.F. Eyes
180	24.10.17	P	0	Interstitial keratitis and other evidence of syphilis. Is applied as a medical for care.	—	—	—
1369	26. 4.18	P	0	Complains of blood on gums. Dec.	—	—	—
1276	17. 5.18	P	—	N.S.	—	—	—
1357	24. 5.18	P	0	Long-stand[ing] case of hyperm. R. N.[illegible]	0	0	—
1496	21. 6.18	P	—	Dys[illegible] on glans	2	+	—
199	21.11.17	P	—	Interstitial keratitis of right eye. R. of vaccine. Little hard chancre of vaginal lip on account. L. Gumma of palate. Universally enlarged glands. L.	—	—	—
1129	3. 5.18	P	—	Interstitial gum[illegible] of upper and palate. Dec.	0	0	—
1149	3. 5.18	P	—	Gumma[illegible] on[illegible]	4	0	—
399	8. 2.18	P	0	Many[illegible] scars on arms and general pigment. Gumma at[illegible]	3	0	—
1296	19. 7.18	P	—	Soft sores on right[illegible] penis. Acquired about one month before. Glands enlarged.	2	0	—
1213	3. 5.18	P	—	Scar of hard chancre on left side of prepuce. Dec. R. Scars of acquired [illegible] (1895).	2	0	—
618	15. 2.18	P	—	Gumma[illegible]	2	—	—
304	29. 8.17	P	—	Scars of gum on palate. L.	—	—	—
167	9.11.17	P	—	Has[illegible] [illegible] 1916 and treated by	—	—	—
153	5.10.17	P	0	Scars on penis. Dec. Gumma of[illegible] Gumma[illegible]	—	—	—
1169	3. 5.18	P	—	Gumma[illegible] and[illegible] palate. R.	0	0	—
929	1. 4.18	W.P.	0	Is[illegible] [illegible] [illegible] treatment. Impaired[illegible] Gums R. and L. and general[illegible]	2	0	—
34	10.10.17	P	—	Gumma[illegible] Gumma[illegible] and[illegible]	—	—	—
1360	10. 5.18	P	0	Interstitial keratitis of[illegible] of eyes[illegible] R. Gumma[illegible]			

in whom no Direct Evidence of Syphilis was found (continued).

Previous Evidence of Syphilis.	*Probable Infection.* Date.	*Subsequent Evidence of Syphilis.* Effect of Treatment and Relapses.	Further Date.	W.R. Result.
Local antiseptics to sores.	Aug. 1917	Healed.	18. 1.18 5. 4.18	0 0
Local antiseptic. W.R. 0 on 19.4.18.	2. 3.18	Healed.	—	—
Gonorrhœa in 1917.	July 1917	-	—	—
Local antiseptics.	Apr. 1918	Healed.	—	—
Sores on penis circumcised. Buboes, 1916.	Dec. 1916	—	—	—
Gonorrhœa in 1913. W.R. 0, 7.11.17.	6.10.17	Resolved.	—	—
-	20. 2.18	—	—	—
No history of any previous venereal disease.	? 19. 3.18	—	—	—
—	12. 1.18	Not healed.	-	—
Indurated subpreputial sores in sulcus Del. L. and at frænum. *S. pall.* 0, May 1918. Four W.R. tests 0, in May and June.	1. 5.18	—	—	—
Sore on penis. Bilateral inguinal buboes in 1893	1893	-	-	-
Gonorrhœa and Epididymitis Jan. 1918.	? Jan. 1918	-	10. 5.18 9. 8.18	0 0
Sore on penis L.	1912	-	24.10.17	0
—	20.10.17	Healed.	—	-
'Black wash' to sore. W.R. 0, 5.9.17.	29. 8.17	Healed.	2.11.17 3. 5.18 26. 7.18	0 0 0
	? 2. 3.18	—	13. 9.18	0
-	5. 3.18	Healed.	26. 7.18	0
-	Denied	—	—	
—	8. 4.18	Healed.	5. 7.18	0

TABLE 10.

Selected Examples of Men with Sores which were found to contain

B.S. No.	W.R. Date.	Result	Syph.	Clinical	*Presence or Absence of Syphilis* C.S.F. Cells	C.S.F. W.R.	C.S.F. Excess
1499	5. 7.18	0	P	Multiple healing ulcers in coronal sulcus	2	0	—
875	22. 3.18	0	P	Indurated sores on outer side of foreskin	4	0	—
347	5. 1.18	0	P	Mental sore	—	—	—
371	8. 2.18	0	P	Indurated sore at frenum. Marked general adenitis	0	0	—
1192	10. 5.18	0	P	Indurated ring of small ulcers in sulcus	0	0	—
463	18. 1.18	0	P	Indurated moist ulcer on glans near coronal sulcus	—	—	—
1349	31. 5.18	0	P	Septic ulcer perforating foreskin	4	0	—
370	8. 2.18	0	P	Small crusted papule on skin of prepuce. Dis.	4	0	—
143	13.11.17	0	P	Four sores on under surface of prepuce. Marked general adenitis	—	—	—
1333	31. 5.18	0	P	Septic ulcer at torn frenum	2	0	—
557	15. 2.18	0	P	Ulcer with undermined edges in sulcus R.	—	—	—
930	12. 4.18	0	P	Large irregular ulcer on outer surface of prepuce L. Punched out septic ulcer on pubes	4	0	—
257	27.11.17	0	P	Multiple indurated sores in coronal sulcus	—	—	—
1381	14. 6.18	D	P	One indurated ulcer at torn frenum	2	0	—
156	15.11.17	0	P	Sores on under surface of prepuce	—	—	—
157	31.10.17	0	P	Sore in sulcus L. Marked general adenitis	—	—	—
158	31.10.17	D	P	Indurated sore on under surface of prepuce	—	—	—
442	18. 1.18	0	P	Sore at frenum. Several sores on under surface of prepuce	—	—	—
321	2.12.17	0	P	Sore at torn frenum. Marked general adenitis	—	—	—
72	13.11.17	0	P	Indurated sore in sulcus R. Gonorrhœa	—	—	—
1273	17. 5.18	0	P	Indurated ulcers on glans Dsl. and on under surface of prepuce R. Septic torn frenum	0	0	—
1196	17. 5.18	0	P	Healing indurated sore at meatus	8	0	—
1633	5. 7.18	0	P	Septic ulcer at frenum	0	0	—
1218	17. 5.18	0	P	Sore on under surface of prepuce	2	0	—
1326	31. 5.18	0	P	Ulcer at base of penis, R.V	0	0	—
1275	17. 5.18	0	P	Indurated ulcer at torn frenum. Marked general adenitis	4	0	—

Spironema pallidum *and with Negative Wassermann Reactions.*

Previous Evidence of Syphilis.	*Probable Infection.* Date.	*Subsequent Evidence of Syphilis.* Effect of Treatment and Relapses.	Further Date.	W.R. Result.
—	7. 6.18	Healed.	—	—
—	10. 2.18	Healed.	26. 7.18	0
—	8.11.17	Healed	—	—
—	7. 1.18	Healed.	19. 5.18	0
—	6. 3.18	Healed.	—	—
—	4.12.17	Healed.	—	—
—	2. 3.18	Healed	—	—
—	3. 1.18	Healed.	—	—
—	Oct. 1917	Healed.	8. 2.18	0
—	30. 3.18	Healed.	—	—
—	2. 1.18	Healed.	—	—
—	15. 1.18	Healed	7. 6.18	0
—	16.11.17	All healed.	12. 3.18	0
—	Apr. or May 1918	Healed.	—	—
—	Oct. 1917	Healed	22. 2.18	0
—	Aug. 1917	Healed	4. 1.18 19. 7.18	0 0
—	Sept. 1917	Healed.	—	—
—	29.11.17	Healed.	8. 2.18	0
—	Nov. 1917	Almost healed	—	—
—	—	Healed.	16. 8.18	0
-	24. 4.18	Healed.	9. 8.18	0
Two doses of Galyl Apr. and May 1918, i. e. before the demonstration of *S. pallidum.*	28. 3.18	Healed.	-	—
—	10. 4.18	Healed.	—	—
Had three doses of Galyl, Apr. 1918, i. e. before the demonstration of *S. pallidum.*	1. 3.18	-	--	—
—	10. 4.18	Healed.	—	—
—	1. 4.18	Healed.	—	—

TABLE 10 (continued).

Selected Examples of Men with Sores which were found to contain

Ref. No.	W.R. Date.	W.R. Result.	*Present Evidence of Syphilis.* *S. pall.*	Clinical.	C.S.F. Cells.	C.S.F. W.R.	Eyes.
1154	10. 5.18	0	P	Phagedenic ulcer perforating frenum	2	0	
345	5. 1.18	0	P	Indurated ulcer on under surface of prepuce, invading sulcus L.			
393	11. 1.18	0	P	Sore on edge of prepuce L. Bubo L. groin			
796	28. 9.17	0	P	Sores on glans Dsl and body of penis R	—		
326	21.12.17	0	P	Indurated phagedenic sore in sulcus L. Dsl extending on to glans and under prepuce.	—		
929	29. 3.18	0	P	Subpreputial ulcer R. Dsl. near edge of prepuce. Sore in sulcus L.	2	0	
273	30.11.17	0	P	Numerous small abrasions on glans and in sulcus			
1035	19. 4.18	0	P	Septic sore at frenum.	3	0	
1371	7. 6.18	D	P	Hunterian sore on under surface of prepuce Dsl. R.	2	0	—

TABLE 11 *Selected Examples of Men with no Active Lesions except Wassermann*

Ref. No.	W.R. Date.	W.R. Result.	*Present Evidence of Syphilis.* *S. pall.*	Clinical	C.S.F. Cells.	C.S.F. W.R.	Eyes.
198	July 1917	0	—	Nil	—	—	—
1233	17. 5.18	0	—	Scar of deep excavated ulcer on glans to R. of frenum, with urinary fistula at base.	2	0	—
287	7.12.17	0	—	Scar of small sore in sulcus L.	—	—	
81	12. 9.17	0	—	Scar of sore in sulcus	—	—	—
66	24.10.17	0	—	Scar of sore at meatus.	—	—	—
1080	19. 4.18	0	—	Scar of sore on under surface of prepuce R.V	3	0	—
138	14.12.17	0	—	Scar of sore in sulcus R.	—	—	—

Spironema pallidum *and with Negative Wassermann Reactions.*

Previous Evidence of Syphilis.	*Probable Infection.* Date.	*Subsequent Evidence of Syphilis.* Effect of Treatment and Relapses.	Further W.R. Date.	Result.
.	6 4.18	Healed.		–
	Nov. 1917	Healed.	12 4 18	0
	28.10.17	Healed.		-
	Aug. 1917	Healed.	22. 2.18	W.P.
	Nov. 1917	Healed.	5. 1.18 18. 1.18	0 0
Gonorrhœa and W.R. "slight P.", Oct. 1917. Treated with 2·6 grm. Galyl Nov. 1917 Jan. 1918.	June 1917	Healed. ? Reinfection or previous diagnosis incorrect.	14 6.18	0
	Nov. 1917	Healed.		–
	5 2.18 28 4.18	Healed. Healed.		

Healing or Scars of Recently healed Inoculation Sores, and Negative Reactions.

Previous Evidence of Syphilis.	*Probable Infection.* Date	*Subsequent Evidence of Syphilis.* Effect of Treatment and Relapses.	Further W.R. Date.	Result.
June 1917, sore on penis. *S. pallidum* P. W.R. 0. Treated with two doses of Galyl.	Apr. 1917		18 4 18	0
Apr. 1918 ulcer on glans. *S. pallidum* 0. Three injections of Galyl Apr.–May 1918. Rapid healing. 29.4.18, W.R. P.	Jan. 1918			
S. pallidum P. One dose of "914".	Oct. 1917			
S. pallidum P. in Sept. 1917, treated with three doses of Galyl. Sept.–Oct. 1917.	13 8.17		19.11.17 8 2.18	0 0
Sore treated with one dose of "606" on 6.10.17.	Aug. 1917		18 1.18 12 4.18	0 0
S. pallidum P. in sore before healing.	23 2.18			
S. pallidum P. treated with two doses of Galyl.	18.11.17		18. 2.18 26. 4.18 30 8.18	V.W.P. 0 0

TABLE 11 *Selected Examples of Men with no Active Lesions except Negative Wassermann*

Ref. No.	W R Date	Result	S. gall	Present Evidence of Syphilis Clinical	C S F Cells	C S F W R	Eyes
1291	31 7 18			Scars L ear no evidence Del	0	0	
1392	21 6 18	0	0	Hutchinson scars healing no evidence R	0	0	
1282	31 5 18	D		Scars of scars Plaque on tongue Del R	4	0	
1406	14 6 18	0		Healing wound on corona Del scar on umbilicus Del of prepuce	0	0	
1516	5 7 18	0	0	Scars of suspected gumma on sternum L	0	0	
1780	11 8 18	0		N R	0	0	
1446	21 6 18	0		Scars, one at 4th, two more. Two scaphe ulcers on scrotum R and one on prepuce Del	2	0	
937	19 4 18	0		Interrupted scars on edge of prepuce covering glans Del Eight L gluts	1	0	
36	9 11 17	0		Scars of lesions on penis			
1247	17 7 18	0		Scars of lesions on prepuce Del	0	0	

TABLE 12 *Men in the Case Wassermann Stage at which* Spirochæta *were but who later*

Ref. No.	W R Date	Result	S. gall	Clinical	C S F Cells	C S F W R	Eyes
429	1 2 18	0		Indurated scar of ulcer in sulcus Del	0	0	
464	21 12 17	0	0	Multiple lesions, stage of papules			
496	18 [illegible] 17	0	0	Scars on scrotum and penis [illegible]			
1429	9 7 18	0		Indurated healing sore on sulcus Del	4	0	
1462	21 7 18	0		Hypertrophic scar on L of frenum	0	0	

Healing or Scars of Recently healed Inoculation Sores, and Reactions (continued).

Previous Evidence of Syphilis.	*Probable Infection Date.*	*Subsequent Evidence of Syphilis.* Effect of Treatment and Relapses.	Further W.R. Date.	Result
Sore treated with two doses of Galyl. W.R. W.P. on 10.8.17.	July 1917			
Frequent *S. pallidum* tests previously 0. One dose of Galyl 28.5.18, before admission. W.R. D., 14.6.18.	1.5.18	Healed		
S. pallidum P., May 1918.	1.5.18			
S. pallidum P. May 1918. One dose of Galyl in May 1918.	1.5.18	Healed		
Sore on penis. *S. pallidum* P., June 1918.	24.4.18			
Had two doses of Galyl, May and June 1918. Sore on penis. *S. pallidum* P., May 1918.	20.4.18		31.6.18 6.9.18	0 0
S. pallidum P., May 1918. Two doses of Galyl, May and June 1918.	1.5.18	Healed		
S. pallidum P. May 1918.	12.2.18			
Sore on pubes Oct. 1917. *S. pallidum* P. Had three doses of Galyl Oct. 1917.	Sept. 1917			
W.R. P., 2.4.18, with sore on penis. Treated with two doses of Galyl	7.1.18			

pallidum *was not found owing to Previous Antisyphilitic Treat-*
developed Syphilis.

Previous Evidence of Syphilis.	*Probable Infection Date.*	*Subsequent Evidence of Syphilis.* Effect of Treatment and Relapses.	Further W.R. Date.	Result
Local antiseptic treatment	8.11.17	No treatment. W.R. Immune P. with general adenitis and glossitis		
Local antiseptic treatment	30.11.17	Healed	28.12.17	P.
Local antiseptic treatment	Sept. 1917	Healed	31.10.17	P.
Local antiseptic treatment	18.5.18	Healed. Macular syphilide developed before treatment	21.6.18	P.
Hg. treatment for one month	1.4.18		4.6.18	P.

TABLE 13. *Men with Cerebro-Spinal Syphilis also*

Ref. No.	W.R. Date.	W.R. Result.	*S. pall.*	*Present Evidence of Syphilis.* Clinical.	C.S.F. Cells.	C.S.F. W.R.	Eyes.
907	7. 4.18	0	—	Marked general stigmata	50	0	—
1071	26. 4.18	0		Sth. nerve deafness and facial paralysis L.	164	0000	—

TABLE 14. *Men with no active Lesions or with Non-syphilitic Wassermann.*

Ref. No.	W.R. Date.	W.R. Result.	*S. pall.*	*Present Evidence of Syphilis.* Clinical.	C.S.F. Cells.	C.S.F. W.R.	Eyes.
968	12. 4.18	0		Nil	8	0	—
1439	24. 5.18	0		Mercurial stomatitis	—	—	—
111	29.10.17	0		Scar on under surface of prepuce	—	—	—
917	29. 3.18	0		Scar of sore at root of penis V.	2	0	—
1380	2. 6.18	0		Scar of excised sore on dorsum of proximal inter-phalangeal joint of 5th finger L.	0	0	—
921	5. 4.18	0	0	Septic ulcer at frenum	9	0	—
861	8. 2.18	0		Enlarged glands in groin. No lesions of syphilis	—	—	—
660	22. 2.18	0		Scar of sore in sulcus L.	0	0	—

had Negative Wassermann Reactions.

Previous Evidence of Syphilis	*Untreated Infection* Date	*Subsequent Evidence of Syphilis.* Effect of Treatment and Relapses.	Further W.R. Date.	Result.
Sore on penis in 1915 treated with two doses of ·606 and Hg for six months.	1915	—	23. 8.18	0
In Oct. 1917, sore on penis, *S. pallidum* P. Treated with two doses of Galyl.	1.10.17	Free from relapse.	—	—

Lesions who had a Definite History of Syphilis but Negative Reactions.

Previous Evidence of Syphilis.	*Possible Infection* Date	*Subsequent Evidence of Syphilis.* Effect of Treatment and Relapses.	Further W.R. Date.	Result.
Sore on penis and bubo. Feb. 1917. Hg for twelve months. W.R. P., 8.3.17. W.R. P., 30.10.17.	Jan. 1917	—	—	—
In 1916 rash and sore throat. W.R. P. Treated with one dose of ·606; two of ·914; seven of Galyl and 29 injections of Hg.; also inunctions, pills, and mercurol.	Apr. 1916	—	21. 6.18	0
Syphilis in 1909. Two years Hg injections and pills. W.R. P. in 1916 given one dose of ·606 and 24 injections of Hg. W.R. P. 3.May.1917.	1909	—	—	—
In 1914 two sores on penis at visit V. Rooth W.R. P. One injection of ·606 and Hg pills 26.1.17. W.R. P. Dec. 1917. Three injections of Galyl and 12 injections of Hg.	Dec. 1914	—	—	—
Sore on penis and syphilides in 1911. Treated with two doses of ·606 and Hg pills for two years.	1911	—	—	—
Syphilis in Sept. 1917 (Army). Treated with two doses of ·914.	1917	Relapsed without sore throat. Presumably re-infected.	—	—
In Jan. 1918 given three doses of Galyl. Suspicion of a positive W.R. in Dec. 1917.	1907		19. 7.18	
Sore on penis and sore throat. 18 months Hg treatment.	1.11.16		1. 3.18 24. 3.18	0 0

TABLE 14 *Men with no active Lesions or with Non-Syphilitic Manifestations*

Ref. No.	W.R. Date	Result	S. and	Clinical	O.S.F. Date	W.R.	Result
1	2 [illegible]	0	—	Severe [illegible] E	—	—	—
2	31 5.18	0	—	Scar [illegible] in [illegible] Dr. [illegible]	—	—	—
3	17 5.18	0	—	Herpes [illegible] [illegible] [illegible]	3	—	—

TABLE 15 *Selected Examples of Men with Scars or Local Conditions not more fully set out*

Ref. No.	W.R. Date	Result	S. and	Clinical	O.S.F. Date	W.R.	Result
438	18.4.18	0	0	Ulceration of prepuce. A special Database Notes. [illegible] of [illegible] prepuce. Ulceration and [illegible] adenitis.	—	—	—
441	14.6.18	0	—	Inguinal [illegible] [illegible] [illegible] of prepuce [illegible]	—	—	—
660	28.11.17	0	0	Syphilis [illegible] [illegible] [illegible] of prepuce [illegible] Syphilis [illegible]	—	—	—
1337	7.6.18	0	0	Syphilis [illegible] [illegible] [illegible] of prepuce. Syphilis [illegible]	—	—	—
1413	14.6.18	0	—	Chancroid. Acquired [illegible] [illegible] Chancroid [illegible]	—	—	—
[illegible]	1.2.18	0	0	Septic sores at [illegible] [illegible] [illegible] of prepuce. Septic inguinal [illegible]	—	—	—
1394	12.5.18	0	0	Healing sore at frenulum. Chancroid [illegible] Not [illegible]	—	—	—
[illegible]	15.2.18	0	0	Hidebound [illegible] [illegible] Dr. [illegible]	—	—	—
1501	4.3.18	0		Scar of [illegible] [illegible] [illegible]	—	—	—
377	1.12.17	0	0	Ulcerated sore at [illegible] E. [illegible] [illegible] Note [illegible] [illegible] [illegible]	—	—	—
231	28.11.17	0	0	Abscess of [illegible]	—	—	—

Lesions who had a Definite History of Syphilis but Negative Reactions (continued).

Previous Evidence of Syphilis	*Probable Infection.* Date	*Subsequent Evidence of Syphilis.* Effect of Treatment and Remarks	Further W.R. Date	Result.
Sore on scrotum 8 weeks before syphilitic rash. Treated with 255 grains of "914" in April, 1918, and mercury for one month	June, 1918			
Sore on penis 8 weeks before P. Rash, enlarged glands in groin. W.R. P., Jan. 1918. Two doses of "914" Feb., 1918	7 Jan., 1918			
Sore on penis, rash 12 weeks after infection. Hg pills for two years	July		24 9 18	P

who had Negative Wassermann Reactions, were Considered not to develop Syphilis.

Previous Evidence of Syphilis.	*Probable Infection.* Date	*Subsequent Evidence of Syphilis.* Effect of Treatment and Remarks	Further W.R. Date	Result.
—	4 11 17	—	4 2 18	0
Sore appeared 10 days after infection	20 7 18		3 8 18 20 9 18	0 0
—	12 11 17		6 12 17 9 12 17 18 1 18	0 0 0
—	7 2 18		17 5 18 17. 7 18	0 0
—	28 5 18		28 5 18 2 8 18 30 8 18	0 0 0
—	8 12 17		22 3 18 12 4 18 3 5 18	0 0 0
—	25 4 18		22 5 18 28 5 18 26 7 18	0 0 0
—	19 11 17		13 3 18 4 4 18	0 0
Scar on penis	1 4 18		17. 5 18 25 5 18 14. 6 18 28 6 18	0 0 0 0
—	7 11 17		5 1 18 4 2 18	0 0
—	12 9 17	—	19 4 18	0

VIII. Discussion.

It will be observed that among 1,177 men who gave positive Wassermann reactions 1,112 showed more or less conclusive evidence of syphilis.

65 men did not show conclusive evidence; in fact they showed no direct evidence either for or against. As will be seen from the examples given in Table 9 the great majority of these men were suffering from gonorrhœa or sores on the penis in which *S. pallidum* could not be found owing to local antiseptic treatment or to the fact that they were healed or healing. Under these circumstances no evidence of syphilis *can* be available in the absence of general signs. It may only be said that all of these men were, or had been, infected with venereal disease, and therefore that their condition was not inconsistent with a diagnosis of syphilis.

Looking at the evidence from a less judicial point of view we have no difficulty ourselves in accepting the evidence of syphilis supplied by the positive reactions. It is well known to us that if we had refrained from treating these men the majority would have developed manifest signs of syphilis. With regard to the remainder, it is common to observe cases of later syphilis who never had any symptoms originally beyond a 'chancroid' or 'gonorrhœa'. Several examples of this will be found among the illustrative cases; it is a phenomenon particularly well known to neurologists. If such cases had had Wassermann reactions carried out at the beginning in spite of the absence of evidence of syphilis, they would have been positive in many as they were in our series.

To turn now to the other aspect of the question: if we accept the indication of syphilis given by a positive reaction, to what extent are these reactions invariable in cases of syphilis?

This is a subject on which there is great diversity of opinion according to the literature, but in practice it is not so. This diversity depends largely upon a confused classification of material by which cases which are probably cured are still counted syphilitic, and upon incorrect diagnosis.

It is the practice in the literature to give the number of positive reactions in syphilis as percentages of the examples of each stage of the disease.

Primary and 'latent' cases give the lowest positive results and naturally so, since a positive result in primary syphilis depends solely upon the length of infection, while among 'latent' cases it depends upon the efficacy of the treatment which has been applied. It is to be hoped that many of the cases described as 'latent' are actually cured.

Thus we see no object in recording the results in primary or 'latent' syphilis. We obtained in the 620 men with primary syphilis in this series **73 per cent. positive, but in a series at a** civil hospital we should get a much higher percentage, because we should see fewer of the very early cases.

We have no figures to show our results in 'latent' cases because we do not use this classification, and there is no practical value in knowing the percentage positive in such men. 'Latent' cases with a positive Wassermann reaction are included in groups C or D, according to the length of time which has elapsed since infection. They have no external lesions but have of course internal lesions, and therefore there is no object in separating them from the 'manifest' cases. 'Latent' cases with negative reactions (*vide* Table 14, p. 48) are also included in groups C and D, although we have no evidence that they are still syphilitic. There were only 11 in the whole series.

The practical point to decide is how many cases of manifest syphilis give positive Wassermann reactions? That is to say, how many give negative? Or, further, given a man with any lesion or condition which may be syphilitic, what are the chances that it may be syphilitic even though the Wassermann reaction is negative?

If we take our C cases, which include all acute secondary syphilities and some early 'tertiary' up to 18 months from infection, practically all of whom had lesions or the remnants of lesions which had been treated or not treated, we find that we obtained only three negative results out of a total of 471 men. One of these negative cases was Case No. 254 described on p. 14, one was a cerebro spinal case, a 'nerve relapse' (Case No. 1071, Table 13, p. 48), while the third was a relapsed 'tertiary' case (Case No. 46, p. 15).

Case No. 254 was not acute. He was clearly resolving after mercurial inunctions. Therefore we may say that there was no instance (in this series) of a negative reaction in an acute secondary syphilitic with a rash.

Thus when a man has a suspicious rash and shows a negative reaction the chances that the lesion is nevertheless syphilitic are practically *nil*. In fact, when any case of disease is suspected to be recent syphilis and the reaction is negative the diagnosis of syphilis is almost certain to be wrong. This is an attitude which several observers have adopted towards the technique here in use, with satisfactory results. It only requires modification in certain special forms of disease, for instance, in neurological or ophthalmological work.

In the later D cases over 18 months from infection, which include late secondary, tertiary, and 'latent' with positive reactions, it is also very rare to obtain negative results although they are possibly rather commoner.

We have 268 D cases, and two gave negative results namely, one manifest 'tertiary' (Case No. 1271, p. 15), and one cerebro-spinal (Case No. 907, Table 13, p. 48).

It is of interest to note that each of the 'tertiary' cases upon re-application of the reaction now gave positive results.

To sum up the evidence of these figures it may be said that negative reactions in cases of syphilis which exhibit manifest signs are very rare whether they have been treated or not, and

thus the negative test is of very great significance in the exclusion of a diagnosis of syphilis.

Although we are unable to *prove* that every case in the series which gave a positive reaction was syphilitic, nevertheless we are of opinion that a reasonable critic can hardly dispute the overwhelming importance of this result in diagnosis.

It is true that this series does not include examples of certain diseases which have been alleged to induce a positive reaction, and therefore we cannot claim in this place that a positive result is *universally* diagnostic of syphilis. We can, however, justly suggest that, in the absence of such diseases, this positive reaction is conclusive.

With regard to the significance of the test in non-manifest or 'latent' cases no deductions can be drawn from this material. This is a question of the probability of 'cure', and it depends upon factors which are not here under discussion.

NATIONAL HEALTH INSURANCE

MEDICAL RESEARCH COMMITTEE

A Report on the Investigation of an Epidemic caused by Bacillus aertrycke

UNIVERSITY OF TORONTO
JUL 4 1919
LIBRARY

LONDON:
PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE
To be purchased through any Bookseller or directly from
H.M. STATIONERY OFFICE at the following addresses:
Imperial House, Kingsway, London, W.C. 2, and
28 Abingdon Street, London, S.W.1.
37 Peter Street, Manchester.
1 St. Andrew's Crescent, Cardiff.
23 Forth Street, Edinburgh.
or from E. Ponsonby, Ltd., 116 Grafton Street, Dublin.

1919

Price 9d. net

MEDICAL RESEARCH COMMITTEE

The following publications relating to the work of the Medical Research Committee can be purchased through any bookseller or directly from H.M. Stationery Office at the following addresses: Imperial House, Kingsway, London, W.C. 2, and 28 Abingdon Street, London, S.W. 1; 37 Peter Street, Manchester; 1 St. Andrew's Crescent, Cardiff; 23 Forth Street, Edinburgh; or from E. Ponsonby, Ltd., 116 Grafton Street, Dublin.

First Annual Report of the Medical Research Committee, 1914-1915. Cd. 8101. Price 3*d*., post free 4*d*.

Second Annual Report of the Medical Research Committee, 1915-1916. Cd. 8399. Price 3½*d*., post free 5*d*.

Third Annual Report of the Medical Research Committee, 1916-1917. Cd. 8825. Price 6*d*., post free 7*d*.

Fourth Annual Report of the Medical Research Committee, 1917-1918. Cd. 8981. Price 4*d*., post free 6*d*.

Special Report Series

No. 1. First Report of the Special Investigation Committee upon the Incidence of Phthisis in relation to Occupations.—The Boot and Shoe Trade. Price 3*d*., post free 4*d*.

No. 2. Report of the Special Advisory Committee upon Bacteriological Studies of Cerebro-spinal Fever during the Epidemic of 1915. Price 6*d*., post free 7½*d*.

No. 3. Bacteriological Studies in the Pathology and Preventive Control of Cerebro-spinal Fever among the Forces during 1915 and 1916. Price 1s. 6*d*., post free 1s. 8½*d*.

No. 4. Reports upon Investigations in the United Kingdom of Dysentery Cases received from the Eastern Mediterranean.

I. Amœbic Dysentery and the Protozoological Investigation of Cases and Carriers. Price 1s., post free 1s. 2*d*.

No. 5. II. Report upon 878 Cases of Bacillary Enteritis. Price 1s. 6*d*., post free 1s. 8*d*.

No. 6. III. Report upon recovered Cases of Intestinal Disease in the Royal Naval Hospital, Haslar, 1915-16.

IV. Report upon combined Clinical and Bacteriological Studies of Dysentery Cases from the Mediterranean. Price 1s. 6*d*., post free 1s. 8*d*.

No. 7. V. Report upon 2,309 Enteritis 'Convalescents' received at Liverpool from various Expeditionary Forces. Price 2s., post free 2s. 2½*d*.

No. 8. Report upon 5,000 Men returned as Cases of 'Disordered Action of the Heart (D.A.H.)' or 'Valvular Disease of the Heart' (V.D.H.). Price 1s., post free 1s. 1½*d*.

No. 9. A Report upon the use of Atropine as a Diagnostic Agent in Typhoid Fever. Price 1*d*., post free 1*d*. 1½*d*.

No. 10. The Mortality of Boys in Infancy and Childhood. Price 1s. 6*d*., post free 1s. 8*d*.

NATIONAL HEALTH INSURANCE

MEDICAL RESEARCH COMMITTEE

A Report on the Investigation of an Epidemic caused by Bacillus aertrycke

Approved for publication by the Medical Research Committee, 14th November, 1918.

Medical Research Committee.

(*National Health Insurance.*)

The Hon. Walter Astor, M.P. (*Chairman.*

The Right Hon. Christopher Addison, M.D., M.P.

The Viscount Goschen, C.B.E. (*Treasurer.*

C. J. Bond, C.M.G., F.R.C.S. (Hon. Colonel).

Professor William Bulloch, M.D., F.R.S.

Henry Head, M.D., F.R.C.P., F.R.S.

Professor F. G. Hopkins, D.Sc., F.R.S.

Major-General Sir William Leishman, K.C.M.G., C.B., F.R.S.

Professor Noel Paton, M.D., F.R.S.

Sir Walter M. Fletcher, K.B.E., M.D., F.R.S. (*Secretary.*)

15, Buckingham Street,
Strand, W.C. 2.

INTRODUCTION

The Report now published here by permission of the Director General A.M.S., makes contribution to the existing knowledge of an interesting family of organisms, the 'Salmonella' group, and, at the same time, deals with some important questions as to the nature of what is commonly described as 'food poisoning'.

At the present time there is a well-marked cleavage of opinion as to the relations of the organisms included in the 'Salmonella' group to each other and to those of allied groups. The German school continues to describe as *paratyphus-B* those organisms which, whether they give rise to the symptoms of gastro-enteritis or to an illness clinically resembling typhoid fever, give the cultural and fermentation reactions of Schottmüller's *Bacillus paratyphosus B*. This attitude is well exemplified in a recent article by Professor H. Beitzke, 'Zur pathologischen Anatomie der Paratyphus-B-Erkrankungen,' in the *Berliner Klinische Wochenschrift* of July 8, 1918, in which three distinct clinical and pathological types of illness, resembling respectively typhoid fever, gastro-enteritis, and dysentery, are attributed to this organism.

On the other hand, the British school, influenced by the researches of Bainbridge and O'Brien and other workers, tends rather to the opinion that a hard and fast line can be drawn, both on clinical and serological grounds between *B. paratyphosus B* on the one hand and *B. aertrycke*[1] and *B. Gaertner* on the other, while the latter two organisms, though indistinguishable from each other in their clinical manifestations, are held to be separable by serological tests.

The present report makes it clear that the clinical picture produced by *B. aertrycke* while conforming, as a rule, to that of gastro-enteritis, is still liable to vary within wide limits: at the same time the very close serological affinity of *B. aertrycke* to *B. paratyphosus B* is clearly brought out.

But while it is true that the report brings into prominence the close relationship between the different organisms of the Salmonella group, it also demonstrates both the possibility and the desirability of differentiating between them. Even before the laboratory findings were conclusive, or rather, at a time when the laboratory findings tended in the absence of test strains of *B. aertrycke* for comparison, to be misleading, the physicians were firmly convinced that the illness was not paratyphoid fever (B). As soon as test strains of *B. aertrycke* were obtained from London,

[1] In the present Report it will be noticed that the authors prefer to use the Belgian, French, and British spelling of the place-name Aertrycke, forming a duly latinised adjectival term, instead of the German form Aertrycker as used by the Navy.

the bacteriological findings became definite, and it was possible to assert positively that the causative organism was *B. aertrycke* (Neapel). This organism, though closely related to *B. paratyphosus B*, is still specifically distinct. Thus it comes about that the triple typhoid and paratyphoid A and B (T.A.B.) inoculation affords no protection whatever against *B. aertrycke*. This is a point which cannot be too urgently insisted on. In the case of this disease prophylactic inoculation is not attempted, and defective sanitation is therefore liable to be severely punished.

Turning now to the bearing of the present report on 'food poisoning' in general, it is evident that a distinction must be drawn between outbreaks due to food in which, owing to bacterial contamination or other causes, an active toxin is present when the food is eaten, and those in which a pathogenic organism is ingested with the food and subsequently establishes itself in the body. The outbreak now under consideration belongs to the second group. The importance of this point is well brought out by the authors, who show that while bacterial contamination of food by a 'chronic carrier' was almost certainly the cause of the initiation of the outbreak, the occurrence of subsequent cases was due to the usual factors of 'contact' in a community in which 'acute carriers' were numerous.

Medical Research Committee,
15, Buckingham Street,
Strand, W.C. 2.

November 14, 1918.

A REPORT ON THE INVESTIGATION OF AN EPIDEMIC CAUSED BY BACILLUS AERTRYCKE.

IN A DEPOT IN FRANCE.

By Captain H. Marrian Perry, R.A.M.C., and
Captain H. L. Tidy, R.A.M.C. (T.C.).

(Received *August*, 1918.)

CONTENTS.

		PAGE
1.	Discovery of Food Poisoning and Allied Bacilli	5
2.	Review of Investigations of Previous Epidemics	7
3.	History of the Present Epidemic	9
4.	Clinical Characteristics	16
5.	Diagnosis	18
6.	Bacteriology	19
7.	Methods adopted for Control of Epidemic	28
8.	Epidemiology	29
9.	Summary	30

1. Discovery of Food Poisoning and Allied Bacilli.

In 1888, Gaertner isolated from the spleen of a fatal case of meat poisoning and from the suspected meat an organism which he named *Bacillus enteritidis*. This is now known as the *B. enteritidis* of Gaertner and has since been isolated in many outbreaks of food poisoning.

Durham and De Nobele, working independently, isolated in 1898 an organism closely related to that of Gaertner and this they titled *Bacillus aertrycke*.

In 1896, Achard and Bensaude isolated from a patient with symptoms resembling those of typhoid fever an organism differing from the classic Eberth's bacillus. To this organism they gave the name *bacille paratyphique*. Their observation was followed by that of Schottmüller in 1900, who showed that two distinct types of *paratyphoid bacilli* existed, and these were designated later by Kayser under the names of type *A* and type *B* the type *B* of Schottmüller being identical with the *bacille paratyphique* of Achard and Bensaude.

A group of organisms having the same biochemical reactions was thus isolated from two distinct types of disease.

The organism which had been isolated in 1885 by Salmon and Theobald Smith from cases of swine fever and named by Kruse *Bacillus suipestifer* was not considered, at this time, to have any connexion with disease in man notwithstanding the fact that its cultural reactions were identical with the above group of organisms.

The classification and relationships of these organisms was thus exceedingly complicated.

The work of various observers, including Bainbridge and Bayon, has placed the differentiation and classification of the group on a sounder basis. This has been attained by the application of the absorption test. It must, however, be admitted that the value of this test is still a subject of controversy. German writers, notably Uhlenhuth, Hübener, Xylander, and Bohtz, have denied the validity of the deductions drawn from its application. This subject is fully discussed by Eastwood in a report of the Local Government Board, New Series, No. 114, 1917.

Methods of Differentiation.—*Bacillus enteritidis* of Gaertner is readily distinguished from the other members of the group by simple agglutination tests alone. By use of the absorption test, of which details will be given later, *B. paratyphosus B* is differentiated from *B. suipestifer* and *B. aertrycke*. By the same method Bainbridge has proved that the two latter organisms are identical.

The chief characteristics of these organisms are as follows:—

They are all Gram-negative motile bacilli.

They form acid and gas in peptone water containing glucose, mannite dulcite, levulose, arabinose, galactose, sorbite, and maltose.

They do not ferment lactose, raffinose, salicin, saccharose, and inulin.

Litmus milk after a preliminary acidity is rendered alkaline and they do not form indol.

The following table illustrates the serological differences.

Nature of Organism.	*Agglutination.*	*Absorption test.*
B. enteritidis Gaertner	Easily differentiated.	
B. paratyphosus B		Can be differentiated.
B. suipestifer	Indistinguishable	Identical.
B. aertrycke		

Since the recognition of *B. aertrycke* as a causal agent of the symptoms of food poisoning several strains of this organism have been identified and differentiated by means of serological reactions with their respective immune sera. The best known of these are the Newport and Mutton strains, the former recovered by Schütze in 1915 from a fatal case occurring at Newport, the latter being isolated by Hutchison at Newcastle. It is evident that *B. aertrycke* can, by detailed study of its serological reactions, be divided into several special types, a characteristic which is shared by many organisms such as pneumococci, meningococci, and as shown more recently, tetanus bacilli.

2. Review of Investigations of Previous Epidemics.

Professor Bainbridge has given an admirable and detailed review of this subject in his Milroy Lectures for 1912, and the following is a brief *résumé* of his valuable contribution. We wish to take this opportunity of expressing our indebtedness to his researches.

The general characteristics of food poisoning, apart from the clinical features, have been the simultaneous development of symptoms and their limitation to persons who have partaken of some particular article of food.

The term 'ptomaine poisoning' was introduced by Selmi to denote a train of symptoms which he considered to be due to the consumption of food in which autolytic changes had occurred, or in which bacterial action had produced substances which he termed 'ptomaines'. The chief characteristic of this form of poisoning was held to be the onset of symptoms after a very brief latent period. These observations were made at a time when the infection of food by *B. enteritidis* of Gaertner or by *B. aertrycke* had not been recognized, and thus there is no evidence that the symptoms were not due to the presence of these organisms. Latterly this term has been reserved for those cases in which bacteriological investigations both of patients and suspected food have proved negative.

The majority of recorded outbreaks of food poisoning has been proved to be due to *B. enteritidis* of Gaertner or *B. aertrycke*. It has been suggested that the actions of toxins of these bacilli are the cause of symptoms in outbreaks in which a definite causal organism has not been isolated, although conclusive proof in this connexion is lacking.

In those instances in which *infection* with one of these organisms has been proved, the symptoms have been preceded most often by a definite latent period of 12 to 36 hours. On the other hand, in cases in which symptoms set in within a few hours of the consumption of the food, *intoxication* with the products of these bacilli has been held responsible. In every case the possibility of intoxication in addition to actual infection is present, and varies directly with the degree of bacterial multiplication which has taken place, but instances in which the symptoms are attributable purely to a toxaemia are rare or do not exist. The difficulty of proving whether any particular outbreak in which an organism has not been isolated either from food or patients is due to the toxins of these bacilli or to ptomaines has not been overcome.

Outbreaks of food poisoning have been commonest in Germany, but have been recorded occasionally in most European countries. In England the most important have been at Hatton, Chesterfield, Chadderton, St. Anne's, and Salisbury. They have been more common, as would be expected, in the summer than in the winter months. *B. enteritidis* of Gaertner has been less often found than *B. aertrycke*. The clinical features have been closely similar in all the outbreaks, the only variability shown having been in the length of the latent period which in different epidemics has been between

6 and 72 hours. Previously the latent period in any particular outbreak has shown much uniformity, and, as referred to above, is dependent on the dose of organism ingested. The practically simultaneous onset of symptoms in a number of persons and the infrequency of secondary infections has enabled epidemics to be attributed to some definite article of food. In the epidemic at present under consideration two points of importance have been the variability of the latent period and more especially the occurrence of secondarily infected cases.

B. enteritidis and *B. enteritis* will now be considered separately.

B. ENTERITIDIS *of Gaertner.*

This organism is held to be an extremely rare inhabitant of the alimentary canal of healthy persons or of those suffering from symptoms other than food poisoning. It has occasionally been isolated in routine examinations of cases of enteric fever or of diarrhœa. There is no record of its isolation in recent literature which has dealt with extensive examinations of fæces in intestinal affections. It must therefore be considered to appear but rarely in the fæces apart from symptoms associated with food poisoning.

It has been isolated from animals, especially cattle, its presence generally being associated with definite symptoms of disease.

Numerous outbreaks of food poisoning have been caused in man by the consumption of articles infected with this organism, and it has been isolated from the excreta of patients, from the spleen in fatal cases, from the infected food, and from the tissues of the animal from which the meat had been derived.

The meat may possibly be infected in one of three ways: first, intravital infection, the animal being diseased; secondly, infection *post mortem* due to careless slaughtering, the infection arising by contamination with the intestinal contents of a diseased animal; thirdly, introduction of the organism by human carriers.

So far, there has been no evidence that outbreaks have originated through infection of food by human carriers, although secondary cases have arisen by close contact with patients.

Chronic human carriers have never been recorded with the exception of a case reported by Dean in which he isolated the bacillus from the bile and gall-stones of a patient suffering from cholecystitis and from the stools three months after operation.

Bainbridge, reviewing this case, indicated the possibility of infection with this organism through human agency.

B. AERTRYCKE.

So far as we are aware, the occurrence of this bacillus in the human intestine in health has never been recorded and apart from outbreaks of food poisoning it has not been isolated except in a few cases which were clinically diarrhœa. With the exception of three instances published by Capt. W. Fletcher, to which reference is made elsewhere, there is no evidence in recent literature, which covers a large series of examinations of fæces, that this organism has been recovered. The view was advanced by some German writers that

the bacillus was fairly widespread in man, but confusion has always existed there, owing to the fact that it was not differentiated from *B. paratyphosus B.* The fact that it has not been met with in recent investigations is possibly due to the absence of the classical clinical features of food poisoning, when naturally the bacillus would be accepted as *B. paratyphosus B* and the crucial test of absorption of agglutinins would not be applied.

Search for a normal habitat in animals has yielded meagre results. It has been found occasionally in pigs in Germany, but never in England. It has been isolated most frequently from guinea pigs and mice. In food poisoning in man it has been recovered from patients and from meat, most frequently from pork. In the latter connexion it has frequently been observed that the animal was ill before being slaughtered. As mentioned, the original discovery of the bacillus was from cases of swine fever, in which disease it has now been held to be a secondary invader. In many outbreaks, however, there was no evidence that the animals were other than perfectly healthy when slaughtered. In the historical discovery of the organism by De Nobele at Aertryeke it was recovered from the bone marrow of a sick calf, the flesh of which had given rise to the outbreak.

The infection of food by the bacillus may be caused in the same manner as has been referred to under the previous heading, with the exception that no instance up to the present has been recorded of a human carrier, hence this mode of infection has not been seriously considered as a possible cause. In our opinion this factor must now be seriously taken into account in those epidemics where the source of infection has not been traced to the consumption of meat from a diseased animal.

3. History of the Present Epidemic.

The Depot in which the outbreak occurred was opened in June 1917. It was planned to accommodate 3,000 men, but the daily returns were usually 800–1,200 previous to April 1918. During the later days of March and in April, the numbers increased rapidly, as shown by the following figures:—

March	21	.	.	698
..	28	.	.	921
April	4	.	.	2,089
..	11	.	.	3,051
..	18	.	.	3,762

The health of the Depot had been good, and the Daily Sick Parade, with numbers 800–1,200 was usually between 20 and 30. In April, the Sick Parade increased to about 100, accounted for by the greater numbers and to some degree by the physical state of the men entering the Depot. Until April 14, no increase in cases of diarrhœa was noted. On April 15, about 300 men reported sick. Three groups of cases were recognized:

i. Normal sick. About 100.
ii. High temperature, general pains, no diarrhœa. About 50.
iii. Diarrhœa and vomiting. About 150.

The cases of diarrhœa and vomiting resembled clinically the trachoma outbreaks which are common in hospitals and were regarded as such but on April 21 two patients who had been transferred to a General Hospital died. These two fatal cases were investigated by Major Wilson, who isolated from the stools and spleen of each an organism culturally similar to *B. paradysenteriæ Y*, which was agglutinated by a serum specific for this organism. The organism recovered from one of these fatal cases is included in our investigation, and is referred to as *B.* (Hough). Two French children (Feutry) in a farm a short distance from the Depot were taken ill with similar symptoms on April 13, and were admitted to the Infectious Hospital on April 18. One of these died on April 21, and from the stools of both a similar organism was isolated by one of us (H. M. P.). The organism recovered from the fatal case is referred to as *B* (Feutry). In consequence of these cases the Depot was closed for admissions and discharges on April 23.

Progress and Extent of the Epidemic.

From inquiries amongst the men, it appears that the earliest date on which diarrhœa occurred to any extent was April 7. Estimates vary between 20 and 50 cases, but it is evident that very few were severe and only one or two reported sick. Practically no further cases occurred until April 13, on which day considerable numbers were affected. Many of these were severe, and all the three fatal cases (excluding a case of appendicitis) commenced on this day. In the course of April 14 and during the night a large number were affected, and many reported sick the following morning.

The numbers reporting for diarrhœa were approximately as follows:—

April 15	. .	150	April 20 . . 60
„ 16	. .	150	„ 21 . . 20
„ 17	. .	80	„ 22 . . 40
„ 18	. .	70	„ 23 . . 30
„ 19	. .	70	

After April 23 the number of fresh cases did not exceed 10 on any one day.

These figures are no guide to the extent or progress of the outbreak, firstly, because many men did not report sick until the second or subsequent days of the attack, and secondly, because large numbers did not report at all.

Total number affected.

On April 25 the companies occupying the Old Camps, which had been chiefly involved, were paraded and questioned individually. About 200 men were found to this manner. On April 28 the remaining companies were paraded and a further 200 separated.

On April 28 a portion of the Depot was isolated and all men placed there who had been ascertained to have had diarrhœa. At midnight this contained 845 men. In addition 215 had been trans-

ferred to Hospital for clinical and bacteriological investigation, making a total of 1,060.

There is no doubt that this does not represent the total numbers. Of the 2,500 men in the non-isolated portions of the Depot, it is possible that at least half had diarrhœa in various degrees.

Date of Onset and Duration of Epidemic.

Early in May, every man in the Isolated Area was questioned as to the day of onset, and his attack was classified as Mild or Severe on the following rough basis; the passage of 8 motions in the first 24 hours or 18 in the first three days was taken to indicate a severe attack. Of 854 cases, 721 were classified as Mild, and 133 as Severe.

The dates given are unreliable as they fail entirely to tally with the large numbers reporting sick on April 14 and 15.

In cases under observation in hospital the date of the onset and severity of the attack could be ascertained with considerable accuracy, and the results in 277 are tabulated. (Table I.)

These are divided into 'Mild' and 'Severe' on the same basis as defined above. They are also divided into 'Positive' and 'Negative', the positive cases being those from whose stools *B. aertrycke* was isolated.

From this table the following conclusions can be drawn:—

(1) The earliest cases occurred on April 7th.

(2) The greatest number occurred on April 13th and 14th, the cases arising on these days being of special severity.

(3) A large number occurred on April 21st, but the clinical type was much less severe.

(4) The onset of the last positive case was on May 2nd. The bacillus has not been isolated from any case of diarrhœa arising subsequent to this.

Table I.

Date of Onset, Clinical Severity, and Bacteriological Result in 277 cases under Observation in Hospital.

	Mild			Severe			Total
	No.	Fatal	Total	No.	Fatal	Total	
April 7	6		6	1	1	2	8
8				1	1	1	1
9							
10	1	2	3				3
11				1		1	1
12	2		2	1	1	2	4
13	1		1	10	8	18	19
14	5	1	6	19	13	32	38
15	6	2	8	3	2	5	13
16	2	1	3	2	1	3	6
17	2	2	4	3	1	4	8
18	6		6	5		5	11
19	9		9		1	1	10
20	6	1	7	10	1	11	18
21	25	1	26	9	2	11	37
22	4	4	8	4		4	12
23	9	1	10	6	1	7	17
24	7	1	8	6		6	14
25	4	1	5	3	2	5	10
26	2	1	3		1	1	4
27	2	1	3				3
28	4		4	3	2	5	11
29	2		2	2		2	4
30	3		3	1		1	4
May 1	3	1	4	1		1	5
2	6	1	7	1		1	8
3	4		4	1		1	5
Total	126	24	151	92	57	149	277

Variations in Clinical Severity during progress of the Epidemic.

The clinical severity of the epidemic at different dates has been estimated by calculating the percentage of "severe" cases compared with the total cases occurring in successive four-day periods. The results are as follows:—

Dates	Total Cases	Clinically Severe	Percentage	Bacteriologically Positive	Percentage
April 7–10	19	3	15	11	58
11–14	69	27	39	31	45
15–18	87	43	49	9	10
19–22	93	39	42	57	61
23–26	48	20	41	23	48
27–30, May 1–3	36	11	31	5	14

These figures are represented graphically in Tables II and III.

The clinical severity evidently rose rapidly to a maximum, followed at first by a rapid fall, and subsequently by a slower decrease. The diminution in severity is well illustrated by com-

TABLE II.

Variations in Clinical Severity calculated by percentage of Severe Cases in Successive Periods.

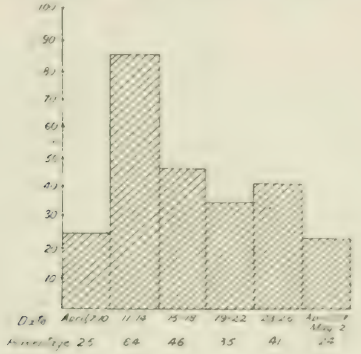
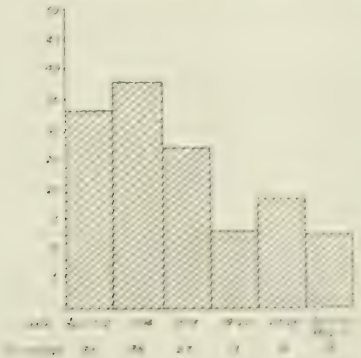


TABLE III.

Relation of Cases Bacteriologically Positive to Total Incidence calculated by percentage in Successive Periods.



parison of the two periods April 11–14 and 19–22. The largest number of cases under observation had their onset in the latter period, but the severe cases were much fewer than in the earlier period.

This variation was fully confirmed by observation in the wards. Practically all the patients whose condition exhibited prolonged resistance to treatment had been attacked in the earlier stages of the epidemic. A fallacy may be introduced here by the fact that they were obviously exposed to re-infection, probably on many occasions, between the original attack and their transfer from the Convalescent Depot to Hospital subsequent to April 23rd.

The percentage of cases bacteriologically positive similarly shows an early maximum followed by a rapid fall.

The Influence of Typhoid-Paratyphoid Inoculation.

In order to determine whether inoculation with typhoid-paratyphoid vaccine gives protection in any degree against an infection with *B. aertrycke*, the date of the last inoculation was taken for all men reporting for diarrhœa and placed in the Isolated Area as described above. These figures were analysed in order to ascertain, first the interval in months since the last inoculation and secondly the percentage who had not been inoculated within twelve months. The results are recorded in Table IV.

Of 851 men from whom data were obtained, 630 had been inoculated within one year, the mean interval being 6·3 months. A further 201 had received their last inoculation between one and two years previously, the mean interval being 15·1 months. For the total 831 cases who had been inoculated within two years, the mean interval is 8·4 months. Of the 851 men, 26 per cent. had not been inoculated within 12 months.

As explained previously, the cases of diarrhœa were divided clinically into 'severe' and 'mild' groups. Of the 851 men, 128 were recorded as having 'severe', 708 as having 'mild' attacks and 15 were unclassified. The data have also been analysed separately for these two sub-groups in the same manner, and the results are found to be closely similar in the two classes.

For comparison the same data with regard to inoculation were obtained from 848 men in the Depot who denied having suffered from diarrhœa. Of these, 607 had been inoculated within one year, the mean interval being 6·7 months. A further 211 had received their last inoculation between one and two years previously, the mean interval being 15·1 months. For the total 818 men who had been inoculated within two years, the mean interval is 8·9 months. Of the 848 men, 29 per cent. had not been inoculated within 12 months.

For the total group of those who had suffered from diarrhœa (Group I), for the two sub-groups of 'severe' and 'mild' attacks (Groups I *a* and I *b*), and for the control group (Group II), who denied having suffered from diarrhœa, the figures are closely similar.

From these results it appears that inoculation with typhoid-paratyphoid vaccine does not protect against infection with *B. aertrycke*, nor after infection does it influence the clinical severity of the condition.

Table IV.

Typhoid-Paratyphoid Inoculation.

(Intervals since last inoculation.)

Group I. *Men suffering from Diarrhoea.*

		Number	Mean Interval in Months	Mean Interval in Months Inoculation within 2 years
Total Number		851	—	—
TAB Vaccine	Within 12 months	630	6·3	8·4
	Between 12-24 months	201	15·1	
	Over 2 years	9		
Typhoid Vaccine		9		
No Inoculation		2		
Percentage with interval exceeding 12 months = 26				

Group I A. *Diarrhoea clinically 'Severe'.*

Total Number		128	—	
TAB Vaccine	Within 12 months	89	5·8	8·0
	Between 12-24 months	31	14·8	
	Over 2 years	4		
Typhoid Vaccine		4		
Percentage with interval exceeding 12 months = 29				

Group I B. *Diarrhoea clinically 'Mild'.*

Total Number		708		
TAB Vaccine	Within 12 months	529	6·3	8·5
	Between 12-24 months	167	15·2	
	Over 2 years	5		
Typhoid Vaccine		5		
No Inoculation		2		
Percentage with interval exceeding 12 months = 25				

Group II. *Men not suffering from Diarrhoea.*

Total Number		848		
TAB Vaccine	Within 12 months	607	6·7	8·9
	Between 12-24 months	211	15·1	
	Over 2 years	18		
Typhoid Vaccine		10		
No Inoculation		2		
Percentage with interval exceeding 12 months = 29				

Marris's Atropine Reaction.

The 'Atropine Reaction' which has been brought into use by Major H. F. Marris as a test for enteric infections was performed in 19 unselected patients. The technique employed was that described by Major Marris (Medical Research Committee, Special Report Series, No. 9).

The results are tabulated in Table V. A summary of the results follows :—

Atypical Test

	Number	Day of Disease tested	Bacteriological		Clinical Condition	
			Pos.	Neg.	Severe	Mild
Positive	9	25	8	1	7	2
Negative	10	28	3	7	3	7

It appears that the test may be either positive or negative, a positive reaction being referable either to a positive bacteriological result or to the clinical severity of the attack.

TABLE V.

Atypical Tests.

Number of Case	Day of Disease	Atypical Test			Bacteriology		Clinical Condition	
		Percentage	Titre	Result	Pos.	Neg.	Severe	Mild
1	22	60-	64	+	pos.		severe	
2	23	77-	79	+	pos.		severe	
3	15	60-	64	+	pos.		severe	
4	22	82-	88	+	pos.		severe	
5	30	92-	96	+	pos.		severe	
6	31	90-	94	+	pos.		severe	
7	24	60-	80	+	pos.		severe	
8	24	72-	76	+	pos.			mild
9	22	80-	74	-	pos.	neg.		mild
10	24	120-	112	+	pos.		severe	
11	42	84-	100	+	pos.		severe	
12	42	72-	68	+	pos.			mild
13	18	100-	104	+	pos.			mild
14	8	68-	108	+	pos.			mild
15	24	96-	120	+	pos.			mild
16	21	92-	96	+	pos.			mild
17	40	100-	96	+	pos.		severe	
18	14	88-	76	+	pos.			mild
19	23	100-	102	+	pos.			mild

4. CLINICAL CHARACTERISTICS

On April 15 when the first large number reported sick, two clinical types were recognized.—(A) Characterized by high temperature, general malaise, various pains but no diarrhœa. (B) Characterized by diarrhœa and vomiting, the temperature usually being normal or but slightly raised.

With regard to Group A, many were transferred to various hospitals. Diarrhœa occurred later in a few scattered instances. In nearly 100 cases the stools were examined but in one only was a bacillus found resembling *B. enteritidis*. This group may be considered to be similar to the pyrexial condition which has lately been widespread and unconnected with infection due to *B. enteritidis*. Apparently two epidemics were present simultaneously.

Group with Gastro-Enteritis.

Latent period. Several cases developed symptoms within 6 hours of admission to the Depot. One severe case had been discharged for 28 hours before the onset of diarrhœa.

Premonitory Symptoms. In a few instances headache and malaise were present for a period up to 24 hours previously, but usually these were absent.

Onset. Sudden. Abdominal pain and diarrhœa. Vomiting common. Chills, sweats, and headache frequent. Abdominal pain is severe and syncope may occur, but tenesmus is not marked.

Progress. All degrees of severity occurred. In the majority of cases the initial symptoms are the most severe and improvement may be rapid. In many cases the bowels were opened freely for 3–6 hours only. In severe cases the diarrhœa continued frequent for 4–7 days or longer. Headache rarely persists after the first day.

Vomiting. Vomiting occurred at the onset in the majority of cases. Continuation of vomiting was the most serious symptom met with. In several of the severest cases it did not commence until the second day.

Temperature. The mild cases were apyrexial. In severe forms slight pyrexia of 99–99·5, was frequent and rarely the temperature reached 100–101 for one or two days, but the condition even when severe is but little associated with pyrexia and the temperature is often subnormal.

Tongue. Usually clean even in severe cases. Occasionally slight fur.

Character of the Stools. In severe cases watery stool with a little faecal matter. Blood rare and slight. Mucus absent. In milder forms, stools soft and brown.

Pulse. Increased temporarily in the acute stage. Infection with *B. dysenteriæ* has no specific influence on the heart, and there is no subsequent tachycardia. Marris's Atropine Reaction may be positive.

In the abdomen there is nothing characteristic. The spleen is not palpable. There is no rash.

Complications. Rare.

Appendicitis developed acutely in four cases and operations were performed. One patient subsequently died with paralytic ileus. In each instance evidence of previous attacks was present. In three other cases, at least, some inflammation of the appendix was probably present. The most obvious explanation is that the intestinal disturbance caused irritation of a previously diseased appendix.

Pneumonia and *otitis media* were not observed to occur.

Bowels. Subsequent to the acute attack, the bowels tend to be irregular. The mild cases and those with a short attack frequently develop constipation which may be obstinate for many weeks. In the severe cases the bowels generally remain loose and a certain degree of diarrhœa continues. In both classes many cases occur of alternating constipation and diarrhœa.

Weakness depends entirely on the severity of the diarrhœa and

vomiting, and improvement is rapid if the bowels can be regulated. The appetite is recovered immediately the vomiting ceases.

Mortality. Four cases proved fatal, one of these being due to appendicitis and ileus. In the other three cases, in all of which the onset was on April 13th, the predominating symptom was uncontrollable vomiting.

Autopsy. In the two cases in which it was possible to perform an autopsy, the post-mortem appearances were identical and were those of an acute gastro-enteritis. Small petechial haemorrhages were evident in the stomach and in the small and large intestines. The Peyers patches were unaffected and there was no ulceration. In both cases the organism was recovered from the bile and spleen.

Treatment. The main problem in treatment is the regulation of the bowels after the cessation of the acute period. Many methods were tried on different series of cases. With subsequent looseness of the bowels the best results were obtained with large doses of Bismuth, 100 to 150 grains daily with Tinct. Chloroformi et Morphinae Co. minims 5 to 10, three or four times daily.

In cases with alternating diarrhoea and constipation, bismuth and chlorodyne was given regularly, the constipation being treated with enemata saponis while continuing the bismuth mixture.

For persistent constipation 'Mist. Alba' was given regularly in doses of 2 to 4 drachms three times daily, and liquid paraffin, half to one ounce a day. Sabol produced no recognizable effect.

The small intestines being mainly involved, rectal washes and starch and opium enemata do not produce the good results so often seen in dysenteric conditions.

A moderate diet has no bad effects after the acute attack has passed. The appetite is rapidly regained, the tongue is clean and dyspepsia is absent, and a prolonged low diet did not appear to diminish the frequency of the motions.

5. Diagnosis.

The chief conditions of importance from which the diagnosis has to be made are dysentery and enteric fever.

From *dysentery* and forms of ulcerative colitis, it is distinguished readily by the character of the stools. A small amount of blood may be passed during the acute onset, but never persists. Mucus rarely absent from dysenteric stools is never present even when the diarrhoea has continued subsequently for several weeks. A case of dysentery was admitted among a large number of these patients and was quickly recognized by the character of the stools.

From *enteric fever* it differs in the suddenness of its onset and the rapid attainment of its maximum severity. One case of enteric fever occurred during the epidemic. The diagnosis was made clinically within a few days, and from the faeces a bacillus was isolated which was proved by absorption to be a *B. paratyphosus B.* Another case admitted in the early days to the enteric ward with a history of having had *B. paratyphosus B* isolated proved on investigation, to have come from the epidemic camp through another hospital. Clinically the case had no

resemblance to enteric fever, and the organism finally proved to be *B. aertrycke*.

Hospital diarrhoea. Short outbreaks of diarrhoea are common in hospitals and camps. The symptoms are identical with those due to *B. aertrycke*, but in general are milder.

On one occasion a ward containing patients convalescent from the *B. aertrycke* outbreak was attacked during the night by such diarrhoea in common with other wards. The stools from these men were being examined bacteriologically daily, and specimens were taken in accordance with routine. Although the faeces from upwards of sixty men were thus examined at an exceptionally early period, in no instance was either *B. aertrycke* or *B. enteritidis* of Gaertner present. It is evident that these bacilli are not in general the cause of such outbreaks.

6. Bacteriology.

An organism was isolated from 75 cases at the Depot, also from two French children (Feutry) who came under our investigation, and from a fatal case (Hough) examined by Major Wilson. These latter cases, as indicated above, were also connected with the Depot. The organism was thus isolated in a total of 78 cases, in many of them repeatedly.

The organisms isolated from these various cases were consistent in their cultural and serological characteristics, which were as follows:—

Morphology. A Gram-negative bacillus, actively motile and tending to occur in long filaments.

Biochemical Reactions. Incubation of cultures over a period of twenty-one days showed no action on lactose or saccharose. The organism fermented glucose, mannite, and dulcite with the formation of acid and gas, rendered litmus milk permanently alkaline, and did not produce indol.

Serological Reactions. All of the strains were agglutinated by specific sera for *B. paratyphosus B* and *B. aertrycke*. The variation in titre was so slight that the strains could not be separated from each other, nor could the identity of the organism be established by a simple agglutination test.

Pathogenicity. A rabbit weighing 1,015 grammes inoculated intraperitoneally with 1 c.c. of a twenty-four hour broth culture, died in seventeen and a half hours. Beyond a slight haemorrhagic exudate at the site of inoculation no other lesions were evident. The organism was recovered from the spleen and heart's blood.

A second rabbit, weighing 860 grammes, inoculated with 0·5 c.c. by the same route died in seventy hours. *Post-mortem*, the appendix and caecum were intensely inflamed. The organism was recovered from the spleen, bile, and heart's blood.

The *cultural characteristics* being common to the *Paratyphoid B* food poisoning group (*B. enteritidis* of Gaertner and *B. aertrycke*) it became necessary to establish the identity of the organism by further tests.

A. *Exclusion of* B. enteritidis *of Gaertner.* The fact that the

sera of patients suffering from food poisoning due to *B. Gaertner* agglutinates that bacillus but has little or no action on *B. paratyphosus B* or *B. aertrycke* was first taken into consideration. The serum of six patients was put up with an emulsion of *B. Gaertner* in dilutions of from 12·5 to 250. In no case was any agglutination evident.

This was followed by a further series of agglutination tests, using a specific agglutinating serum for *B. Gaertner* against six strains of the organism which had been isolated. The results were uniformly negative.

B. *Exclusion of B. paratyphosus B.* The organism being agglutinated by the specific sera for *B. paratyphosus* and *B. aertrycke* in the same titre, it was necessary to adopt the method of the absorption of agglutinins to establish its identity.

Two well-known strains of *B. aertrycke* (Mutton and Newport) were used in this test, together with specific sera for the Newport strain, *B. paratyphosus B* and *Bacillus* (Hough) and (Feutry), the latter sera being obtained from rabbits which had been immunized with these organisms.

A table illustrating the results of these tests is appended.

Two facts were conclusively established by these absorption tests.

(1) That the organism in question was *B. aertrycke* and corresponded with the Newport Strain.

(2) That the strains isolated from Hough and Feutry [*B.* (Hough) and *B.* (Feutry)] were identical.

Note on the Absorption Test.

The nature of the absorption test is so well known that it would appear unnecessary to recapitulate the principles on which it is based. There are, however, a few points illustrated in Table VI which call for a brief review of the rationale of the test.

In the first place, the necessity for its application arises only when dealing with organisms giving similar biochemical and agglutination reactions, as it is then the only means of differentiating members of a group which bear close serological relations to each other. By its means the true nature of a serum or of an unknown organism can be readily determined. It is dependent on the fact that the whole of the specific agglutinins as well as the co-agglutinins can be removed from a serum by saturating it with the homologous organism, whereas by saturation with a closely related organism only the co-agglutinin for that organism is removed and the specific agglutinins are left either intact or little affected. It is generally stated that the specific agglutinins are little changed, but this appears to be dependent on the degree and duration of the saturation of the serum. This point is illustrated on the above table. For example, the specific agglutinins in the sera, Hough, although very markedly diminished by saturation with a closely related bacillus (*B. paratyphosus B.*), have not been entirely removed, whilst saturation with the homologous organism [*B.* (Hough)] has caused their complete disappearance. The converse,

illustrated by saturation of a *B. paratyphosus B* serum with *B.* (Hough), is also evident.

Further, it may be noted that the various sera prepared with this group of organisms may differ to a marked degree in their specificity. This is illustrated in the present series especially as regards *B. aertrycke* (Mutton), the end titre of this serum being far higher for the homologous organism than for the allied members of the group, whereas the sera prepared with other bacilli agglutinate the related organisms in the same degree.

When carrying out a long series of experiments the standardization of the test becomes necessary if the final results are to be at all comparable, and attention was directed to several important points which may be summarized as follows:—

1. The use of standardized suspensions of organisms of a definite bacterial content in the determination of the end titre of the sera employed.

2. The necessity for the careful adjustment of the reaction of the medium used in growing the cultures, and in making the saturations, the avoidance of incorporation of the medium in the suspension, as it is evident that the agar may act as a protective colloid and so alter the degree of agglutination.

3. The use of freshly prepared sera rather than those which have been stored for many months.

The technique employed is outlined below:—

1. The serum was used in a dilution of 1 in 100. The amount employed in each absorption experiment was 2 c.c.

2. Twenty-four hour growths of five large agar slopes of the organism were used in each test. The serum was saturated by scraping the growth carefully from the medium with a platinum wire and then emulsifying in the diluted serum.

3. The saturated serum was incubated at 37° C. for two hours and left standing at room temperature for twelve hours before centrifuging.

4. In the determination of the end points of agglutination of the various sera the macroscopic method, using formalized emulsions of the various organisms, was employed. The emulsions were of a constant bacterial content, and sufficient were prepared to cover the estimations necessary for the whole series.

5. The agglutination tests were carried out by incubation at 50° to 55° C. for two hours.

Table VI.

Absorption Tests.

Serum	End Point of Agglutination Titre for				
	B. Hough	*B.* Beatty	*B.* [illegible] Mutton	*B.* [illegible] Newport	*B. para. B*
1. *B.* Hough original titre	25,000	25,000	25,000	25,000	25,000
Absorbed with					
B. Hough	< 500	< 500	< 500	< 500	< 500
B. Beatty	< 500	< 500	< 500	< 500	< 500
B. [illegible] Mutton	2,500	3,000	< 500	2,500	< 500
B. [illegible] Newport	< 500	< 500	< 500	< 500	< 500
B. para. B	3,000	3,000	2,000	3,000	< 500
2. *B.* [illegible] Newport original titre	125,000	125,000	125,000	125,000	125,000
Absorbed with					
B. Hough	< 500	< 500	< 500	< 500	< 500
B. Beatty	< 500	< 500	< 500	< 500	< 500
B. [illegible] Mutton	28,000	25,000	< 250	28,000	< 500
B. [illegible] Newport	< 500	< 500	< 500	< 500	< 500
B. para. B	28,000	25,000	12,000	28,000	< 500
3. *B. para. B* original titre	25,000	25,000	25,000	25,000	25,000
Absorbed with					
B. Hough	< 500	< 500	< 500	< 500	12,000
B. Beatty	< 500	< 500	< 500	< 500	12,000
B. [illegible] Mutton	< 500	< 500	< 500	< 500	7,000
B. [illegible] Newport	< 500	< 500	< 500	< 500	12,000
B. para. B	< 500	< 500	< 500	< 500	< 250
4. *B.* [illegible] Mutton original titre	6,000	6,000	50,000	6,000	6,000
Absorbed with					
B. Hough	< 500	< 500	[illegible]	< 500	< 500
B. Beatty	< 500	< 500	30,000	< 500	< 500
B. [illegible]	< 500	< 500	< 500	< 500	< 500
B. [illegible] Mutton	< 500	< 500	30,000	< 500	< 500
B. para. B	600	600	30,000	600	< 500
5. *B.* Beatty original titre	5,000	5,000	[illegible]	[illegible]	[illegible]
Absorbed with					
B. Hough	[illegible]	[illegible]	[illegible]	< 500	< 500
B. Beatty	[illegible]	[illegible]	< 500	< 500	[illegible]
B. [illegible] Mutton	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
B. [illegible] Newport	< 500	< 500	[illegible]	< 500	< 500
B. para. B	[illegible]	[illegible]	[illegible]	3,000	[illegible]

Six strains of the organism in addition to those quoted in the above table were submitted to the absorption test. Thus a total of eight strains of the organism isolated during the epidemic were tested, and in all cases the results proved consistent.

More recently two organisms from a different source have been submitted to one of us (H.M.P.) for investigation.

One (Organism 'A') was recovered from the intestinal contents of a fatal case of gastro-enteritis, the other (Organism 'B') was isolated from the blood of a patient suffering from a short pyrexia with abdominal pain and diarrhoea.

The work that has so far been completed on these organisms indicates their relationship to the Mutton strain of *B. aertrycke*. The results of absorption tests will be seen on reference to Table VII.

There has, as yet, been no opportunity of ascertaining whether the Mutton strain of *B. aertrycke* will remove all the agglutinins from immune sera prepared with these bacilli, an essential point in definitely establishing their identity.

These cases emphasize the necessity of more detailed serological investigation in cases of diarrhoea and vomiting when an organism having the cultural characteristics of *B. paratyphosus B* has been isolated.

Table VII.

Table of Absorption Tests.

Serum	End Point of Agglutination Titre for				
	Organism 'A'	Organism 'B'	*B. para. B*	*B. aertrycke* Newport	*B. aertrycke* Mutton
1. *B. aertrycke* Newport original titre	14,000	14,000	15,000	14,000	14,000
Absorbed with Bacillus 'A'	< 500	< 500	< 500	4,000	< 500
,, 'B'	< 500	< 500	< 500	4,000	< 500
2. *B. aertrycke* Mutton original titre	30,000	30,000	7,000	7,000	30,000
Absorbed with Bacillus 'A'	< 500	< 500	< 500	< 500	< 500
,, 'B'	< 500	< 500	< 500	< 500	< 500
3. *B. paratyphosus B* original titre	6,000	6,000	8,000	6,000	6,000
Absorbed with Bacillus 'A'	< 500	< 500	< 500	< 500	< 500
,, 'B'	< 500	< 500	< 500	< 500	< 500

Methods of Isolation.

Blood culture. This has proved of no value in the series of cases in which it was attempted. It is probable that a septicaemia occurs only in the extremely severe cases.

Stool cultures. In early cases there appears to be little difficulty in isolating the organism from the stools.

The method which gave best results is as follows:

An emulsion of the fæces in peptone broth was inoculated into tubes of a 1 in 200,000 solution of brilliant green in peptone water, incubated for twelve hours and plated on Conradi-Drigalski medium.

A series of twenty cases were selected with a view to the determination of the value of this method in comparison with direct plating of the faecal emulsion.

The result was as follows:—

Fourteen were negative when plated direct and positive when passed through brilliant green.

Six were positive when plated direct and also on passage through brilliant green.

Urine cultures. In sixty cases repeated bacteriological examination of the urine was made. In one case only was the organism isolated and then only on one occasion.

The method employed was passage through brilliant green peptone broth.

Specific Serum Reactions.

In previous reports of epidemics caused by this organism, attention has been directed to the appearance of specific agglutinins in the patients' sera as an aid to diagnosis.

A series of twelve cases, proved positive by stool culture, was selected with a view to the determination of the value of this test.

The fact that all these patients had been inoculated with the typhoid-paratyphoid vaccine and that inoculation agglutinins were evident in their sera for *B. paratyphosus B* and correspondingly for *B. aertrycke*, was taken into consideration.

The tests were repeated at intervals of four days to demonstrate any change in titre for *B. aertrycke* should it manifest itself.

In all cases the titre for both *B. paratyphosus B.* and *B. aertrycke* remained unchanged.

Opportunity for this determination in non-inoculated individuals was limited to three cases.

Two of these evinced no response, one showed a definite agglutinin curve which is represented in the appended graph (Table VIII).

The agglutinins in this case had appeared by the eighth day of the illness reached a maximum about the twentieth day and fell rapidly from this day onwards.

A positive serum reaction is distinctly valuable in the diagnosis as it is extremely rare to find the serum of healthy individuals agglutinating *B. aertrycke*.

The results of administration of a vaccine of *B. aertrycke* (Newport strain) to two healthy men is illustrated in Tables IX and X.

The former graph represents the agglutinin production in a non-inoculated individual, the latter the response shown in a subject who had some time previously been given a typhoid-paratyphoid

TABLE VIII.

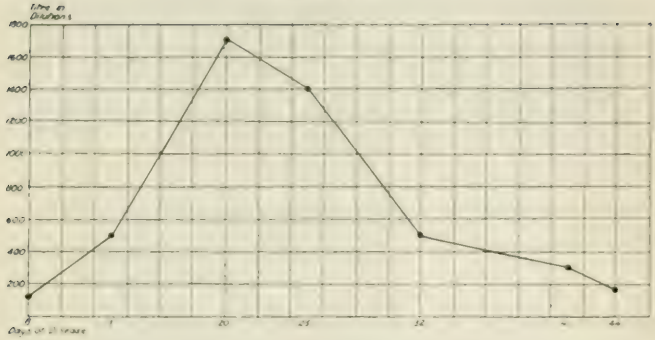
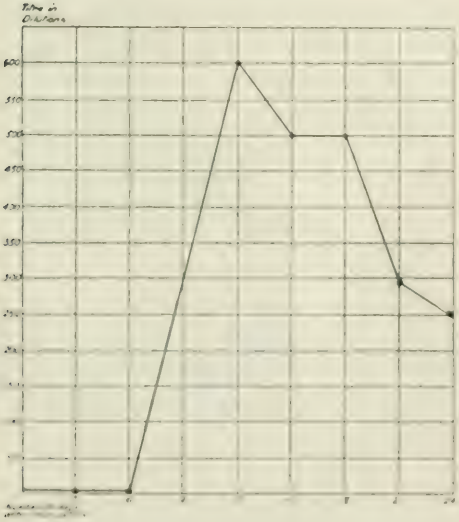


TABLE IX.



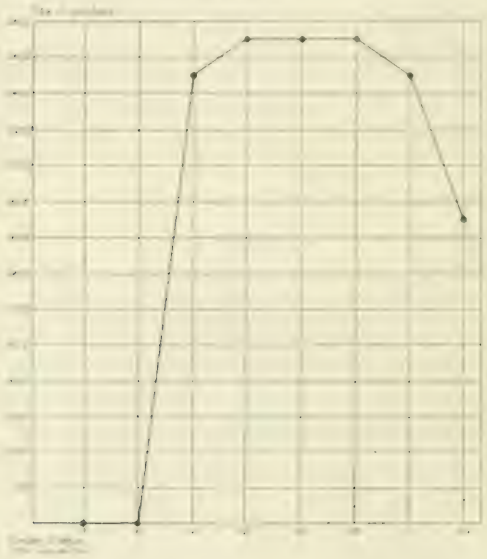
vaccine but in whom the agglutinins for these organisms had disappeared from the serum.

In both cases agglutinin estimations, using emulsions of *B. enteritidis* (Newport strain), were made at intervals of three days. The usual delay in response is apparent, the sera failing to give evidence of a positive reaction until about the eighth day.

The response, as would be expected, was specific, the sera agglutinating *B. enteritidis* and *B. paratyphosus B.*

The greater response evident in the subject who had already received typhoid-paratyphoid vaccine may partly be due to the

TABLE X.



paratyphoid factor, but is much more probably to be accounted for by the fact that the mechanism of production, already elaborated by the previous vaccine, was more susceptible to stimulation.

The dose of vaccine given to both subjects was 200 millions; the reaction was not unduly severe, corresponding to that experienced after typhoid-paratyphoid inoculation.

Duration of Period of Infectivity, &c.

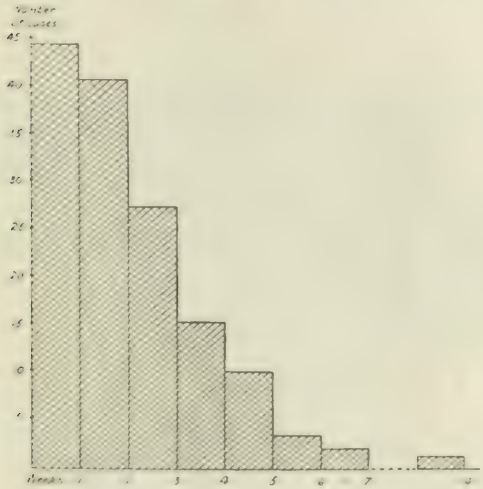
The literature on the subject of meat poisoning due to this organism, to which it has been possible to obtain access, makes no mention as to the rapidity with which the bacillus ceases to appear in the excreta of infected patients.

Three cases have been reported by Captain Fletcher from the Laboratory of the University War Hospital, Southampton, in which he isolated an organism, identified as *B. aertrycke*, in the routine examination of soldiers convalescent from diseases due to the dysentery and enteric group of bacilli.

In two cases, nineteen and eight weeks had respectively elapsed since the onset of the illness; in the third case no record is given of the period of convalescence, beyond the fact that the patient's temperature had been normal for two weeks before admission to hospital.

TABLE XI

Table illustrating Duration of Period of Infectivity.



In two cases the organism was recovered from the urine, and in the third case from the stools.

English writers have denied the occurrence of the organism in the stools of healthy men; it has, however, been isolated from cases which were clinically summer diarrhœa.

The belief amongst certain German writers is that it has a wide distribution and is not uncommonly present in the alimentary canal of healthy individuals, but these results must be discounted as the criterion of the absorption test had not been applied.

It became a matter of considerable importance to obtain some definite data on the subject, and to obtain evidence, if such existed, that the organism continued to be excreted for a prolonged period by infected subjects, as human carriers might constitute a serious source of infection.

Forty-four positive cases were selected and careful stool examinations were made as far as possible daily.

The accompanying chart (Table XI.) illustrates the varying periods at which these cases became free from infection. It will be noted that 50 per cent. had ceased to excrete the organism by the end of the fourth week.

From this onwards the number diminished rapidly and by the end of the seventh week two only were positive.

One case still continues to prove positive at the date of this report—fourteen weeks since the date of the onset of the illness.

In a certain proportion of these cases positive and negative examinations alternated at irregular intervals. In the early stage of the disease the great majority were not only repeatedly positive but were excreting a practically pure culture of the organism.

7. Methods adopted for Control of the Epidemic.

From April 23rd, all admission and discharges from the Depot ceased and it was placed in quarantine. The number of men in the Depot on April 25th was 3,530. The Depot on this date consisted of two distinct portions with separate cooking and dining arrangements. These were known as the Old Camp and the New Camp. The majority of cases having occurred in the Old Camp, the first steps taken was a strict segregation of these areas. The Old Camp was further sub-divided into two sections, A and B.

In A were isolated all cases in the Depot from whom a history of diarrhœa was obtained. Section B consisted of the remainder of the men from the Old Camp.

The New Camp was designated Section C.

On April 28th these arrangements were completed, the numbers in the respective sections being as follows:—

Section A . . .	845
Section B . . .	1,998
Section C . . .	646

Sections B and C forming the largest proportion of the men in the Depot it appeared advisable to ascertain the degree of infection of these areas first, so that they might be cleared at the earliest opportunity.

Owing to the large numbers involved and the difficulties in supply of sufficient material the examination of Section A could not be undertaken at the same time, as the detailed examination of 250 cases in hospital was also taxing our resources.

It was decided to investigate a representative proportion of the men in Sections B and C, and for this purpose a 10 per cent. analysis was considered reasonable. The examinations were commenced on May 3, and the results are as follows:—

Section B .	Positive 1 .	Negative 159
Section C	Positive Nil	Negative 80

These examinations were completed on May 10, and as a result it was possible to advise the liberation from quarantine of 2,482 men.

The next step was the investigation of Section A. As the men

in this area had frankly suffered from diarrhœa, it was considered necessary to make a detailed examination as each man was a potential source of infection.

This examination was completed on May 29. The result was as follows:—15 men were found to be infective. The carrier rate being under 2 per cent., it was considered safe to advise the liberation of the remainder of Section A on May 30.

During the period of these examinations it became necessary to establish a special segregation area for cases found to be positive. The men in these special lines were under strict control and wore distinctive hospital clothing. The positive cases in the different areas were transferred automatically to these lines and also positive cases who had been under hospital treatment and were convalescent.

On May 30, 35 men were segregated in this area. It was then decided to carry out five consecutive examinations of the stools of each individual, and this examination is at present being conducted.

8. Epidemiology.

In this connexion two problems have to be considered:—

(*a*) The source of infection of the original outbreak.

(*b*) The subsequent spread and secondary infections.

(*a*) Under this heading it may be stated at once that we have no evidence which would trace the infection to any definite article of food. It was not until April 25th that we were deputed to investigate the outbreak, and on that date bacteriological examination of all articles of food consumed in the Depot yielded negative results.

That the infection was conveyed through the consumption of food seems certain, owing to the illness of two French children who had access to the kitchen for the purpose of collecting pig swill (children Feutry). Both of these children contracted the infection, one with fatal result, and the organism was recovered from their stools. There is no question that they were connected in any way with the origin of the outbreak.

(*b*) In previously reported epidemics of food poisoning, the most striking feature has been the simultaneous onset of symptoms in a number of persons who have partaken of a certain article of food, which has later been proved, in many instances, to be infected with one or other of the food poisoning group of bacilli. It has been very rare to find cases of secondary infection, and where this has occurred it has been attributed to immediate contact with patients who have eaten the infected meat.

In this epidemic, on the other hand, the outstanding feature has been the occurrence of subsequent cases extending over a comparatively prolonged period.

Many of the later cases were admitted to the Depot after the date of the initial outbreak, which fact proves the continued infection of the food supply. Any food to which the original infection could be attributed had long since been consumed. Further, while the source of the food supply was common to many Camps, cases of infection with *B. aertrycke* were limited to this Depot.

In view of these facts any evidence of contamination of the food by human carriers of the organism after the arrival at the Depot units is considered.

The cook-house and dining-hall staff were first investigated. Many of them admitted that they had suffered from diarrhœa and from one of them *B. aertrycke* was isolated from the stools. The history of this man was carefully gone into and was as follows. He had suffered from diarrhœa and the attacks had been recurrent since November 1917. He had been employed as a cook at the Depot since February 1918. Certain conditions in the cook-house may have been favourable to the spread of food infection. This particularly applied to the making of the soup at a long period before consumption, and its storage in open tubs. The only further factor necessary was the presence of a human carrier connected with its preparation.

Under the heading of 'Duration of Period of Infectivity' in this report attention has been directed to the fact that the problem of human carriers of this bacillus had not been worked out. From the evidence which we are able to put forward it is clear that 50 per cent. of the positive cases, which we have followed were free from infection at the end of the fourth week, but in a few instances bacilli are being passed at the present date.

In both *post-mortem* examinations and in one of the animal experiments the organism was recovered from the bile which fact has an important bearing on the possible production of human carriers.

From the above data, we have arrived at the definite conclusion that the occurrence of the secondary infection was dependent on a human carrier, and that the initial outbreak was probably due to the same cause.

9. Summary.

1. The commencement of the epidemic was April 7th.

2. The causal organism was *B. aertrycke* (Aubagne Strain) which corresponded with the strain 'Newport'.

3. The infection was certainly spread by human carriers, either acute or chronic. The origin of the epidemic was in our opinion due to a carrier.

4. Our investigations of outbreaks of diarrhœa in Hospital yielded negative results as far as this organism is concerned.

5. In the bacteriological examination of stools, the method of passage through brilliant green has proved far superior to direct plating.

6. The earlier the examination is carried out, the greater is the probability of isolating the organism.

7. The serological test has proved disappointing as a help to diagnosis and much reliance must be placed on examination of the stools.

8. Inoculation with typhoid-paratyphoid vaccine has apparently not conferred any immunity against this bacillus.

9. Clinically, the disease varies from an acute gastro-enteritis to a mild diarrhœa. The onset is sudden, pyrexia is the exception.

and the course bears no resemblance to enteric. The character of the stools is unlike that of dysentery.

The only sequela is the persistent difficulty of regulating the bowels.

The investigation of the epidemic was undertaken by direction of Colonel H. S. Thurston, C.B., C.M.G., D.D.M.S. of the district. The sanitary measures to combat the epidemic were controlled by Colonel W. W. O. Beveridge, C.B., D.S.O., A.D.M.S. Sanitation to the British Armies in France, and Captain M. du B. Ferguson, Specialist Sanitary Officer to the District.

Our thanks are due to Lieut.-Colonel J. R. Harper, R.A.M.C. (T.F.) for Hospital facilities in investigating the cases, to Captains R. D. Smedley and H. W. Perkins for help in the bacteriological investigation, and to Captain A. Davidson for help on the clinical side. Colonel T. R. Elliott, D.S.O., F.R.S., Consultant Physician, has given us much valuable help and advice. We also wish to express our indebtedness to Dr. H. Schütze, of the Lister Institute who has kindly examined strains of the organisms referred to in this Report, and has confirmed their identity.

Special Report Series—*continued.*

No. 11. The Causation and Prevention of Tri-nitro-toluene (T.N.T.) Poisoning. Price 1s., post free 1s. 2*d.*

No. 12. The Classification and Study of the Anaerobic Bacteria of War Wounds. Price 2s., post free 2s. 2½*d.*

No. 13. An Enquiry into the Composition of Dietaries, with special reference to the Dietaries of Munition Workers. Price 3*d.*, post free 4½*d.*

No. 14. Reports of the Special Committee upon the Standardization of Pathological Methods.
No. 1. The Wassermann Test. Price 3*d.*, post free 4½*d.*

No. 15. A Study of 1,300 Convalescent Cases of Dysentery from Home Hospitals; with special reference to the Incidence and Treatment of Amœbic Dysentery Carriers. Price 6*d.*, post free 7*d.*

No. 16. A Report on the Causes of Wastage of Labour in Munition Factories. Price 1s. 6*d.*, post free 1s. 7½*d.*

No. 17. I. A Report upon the Seasonal Outbreak of Cerebro-spinal Fever in the Navy at Portsmouth, 1916–1917.
II. The Treatment of Cerebro-spinal Meningitis by Antimeningococcus Serum at the Royal Naval Hospital, Haslar, 1915–16–17. Price 2s. 6*d.*, post free 2s. 9*d.*

No. 18. An Investigation into the Epidemiology of Phthisis Pulmonalis in Great Britain and Ireland. Price 1s. 3*d.*, post free 1s. 5*d.*

No. 19. Reports of the Special Committee upon the Standardization of Pathological Methods.
No. 2. The Laboratory Diagnosis of Gonococcal Infections.
No. 3. Methods for the Detection of Spirochætes. Price 1s., post free 1s. 1½*d.*

No. 20. A Study of Social and Economic Factors in the Causation of Rickets, with an Introductory Historical Survey. Price 2s., post free 2s. 2*d.*

No. 21. Reports of the Special Committee upon the Standardization of Pathological Methods.
No. 4. The Diagnostic Value of the Wassermann Test. Price 1s., post free 1s. 1½*d.*

No. 22. An Inquiry into the Prevalence and Aetiology of Tuberculosis among Industrial Workers, with special reference to Female Munition Workers. (*In the Press.*)

No. 23. An Analysis of the Results of Wassermann Reactions in 1,435 Cases of Syphilis or Suspected Syphilis. (*In the Press.*)

No. 24. A Report on the Investigation of an Epidemic caused by Bacillus aertryeke. Price 9*d.*, post free 10½*d.*

The following is published under the direction of the Medical Research Committee by Messrs. Longmans, Green & Co., 39 Paternoster Row, London, E.C. 4:

Milk and its Hygienic Relations, by Janet E. Lane Claypon, M.D., D.Sc. (Lond.). Price 7s. 6*d.* net.

Printed under the authority of His Majesty's Stationery Office
by the University Press, Oxford

R
111
M457
no.16-24
cop.2

Medical Research Council
(Gt. Brit.)
Special report series

Biological
& Medical
Serials

PLEASE DO NOT REMOVE
CARDS OR SLIPS FROM THIS POCKET

UNIVERSITY OF TORONTO LIBRARY